THE END OF THE WORLD

A Scientific Inquiry

BY THE SAME AUTHOR:

MEN OF OTHER PLANETS

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A Scientific Inquiry

by

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TO

CATHARINE BARRY AND S. I. GALE

CONTENTS

Indeed, since the world began, the world will doubtless end, and astronomers are still asked: how could it be brought about?

CAMILLE FLAMMARION.

One

PROPHETS OF DOOM

ONE

PROPHETS OF DOOM

Whereas the end of the world is approaching . . .

This characteristic phrase, which opened the royal proclamations during the tenth century, might have been written today. At present, there is a general and universal physical fear, with only one question: "When shall I be blown up?"

The idea of the end of the world has recurred again and again in the past, and yet the earth has not ceased to exist. However, prophecies in the near and distant past were based upon revelations in the Bible, the superstitions of astrology, or bad scientific theory. Today the warnings come from absolute and irrefutable scientific fact: the basic power of the universe has been released, and man is rapidly attaining a position where he can end the earth as an inhabited world.

The history of the "end of the world" is interesting, for it is also the story of the human mind face to face with its own destiny; and in these days of despair, a review of this history reflects certain aspects of contemporary human behaviour.

During the early ages of the Church, the belief that the end of the world was at hand was universally spread among Christians. In Nero's reign, the great fire at Rome occurred (A.D. 64), which some ancient writers assert was ordered by the notorious Roman emperor. In order to

remove the odium of the conflagration from himself, Nero tried to throw the blame on to the Christians, and many of them were put to a cruel death.

So much cruelty and madness, so many catastrophes, and so many horrors were crowded into the years A.D. 64-70 that there was every indication that the angel of death had spread his wings over the world. There were innumerable prodigies—comets, shooting stars, eclipses, showers of blood, monsters, earthquakes and pestilences. There was the Jewish War with the Romans and the destruction of Jerusalem. And there was the destruction of the ancient city of Pompeii by an earthquake in A.D. 63. The people of Pompeii were still actively engaged in restoring the buildings when, in A.D. 79, Mount Vesuvius vented its force and buried the town in a shroud of ashes and other volcanic debris.

Though there seemed to be ample warning, though the Apocalypse, which was written by St. John in A.D. 69, seemed to announce the second coming of Christ before that generation passed away, the world's end did not take place. The horrible Jewish War came to an end; and Nero, having been deserted because of his tyranny, and having fled to a house four miles from Rome, ended his life on hearing the trampling of horses on which his pursuers were mounted.

Once more it became necessary to interpret the words of the evangelists. On this occasion, the coming of Christ was put off until after the fall of the Roman Empire, and thus considerable margin was given to the commentator. During the fourth and fifth centuries, the weakness of the Roman Empire in both the east and the west was revealed; and in 476, the Roman Empire in the west came to an end. However, the Empire in the east was restored to nearly its

former height of physical power and culture for some time to come.

St. Gregory (544-594), Bishop of Tours and the first historian of the Franks, began his history as follows: "As I am about to relate the wars of the kings with hostile nations, I feel impelled to declare my belief. The terror with which men await the end of the world decides me to chronicle the years already passed, that thus one may know exactly how many have elapsed since the beginning of the world."

This belief in the end of the world was perpetuated from year to year and from century to century, in spite of the fact that nature failed to confirm it. Every catastrophe and every rare phenomenon in nature was regarded as a precursor of the final cataclysm. The belief was so profound that terror haunted the human soul, and preachers successfully worked upon the dread apprehension.

But, as generation after generation passed, it became necessary to define once again the general and universal tradition; and this time the end was expected in the year 1000. Many sects believed that Christ would reign with the saints for a millennium before the day of judgment. The belief took on an exaggerated and sensual form with many, who anticipated a day of general rejoicing for the elect and a reign of pleasure.

During this period many sermons were preached from the enigmatical words of the Apocalypse: "And when the thousand years are expired, Satan shall be loosed out of his prison, and shall go out to deceive the nations which are in the four quarters of the earth . . . and another book was opened, which is the *book* of life. . . . And the sea gave up the dead which were in it; and death and hell delivered up the

dead which were in them: and they were judged every man according to their works. . . . And I saw a new heaven and a new earth. . . ."

Bernard, a hermit of Thuringia (now a state in central Germany, but formerly a region and a republic), used these words of the Apocalypse as the text of his preaching; and in about the year 960, he announced that the end of the world was near. He set the day as that on which the Annunciation of the Virgin should fall on the same day as Good Friday, a coincidence which occurred in 992.

In the year 999 an "invading army" of pilgrims went to the Holy Land to await the Last Judgment at Jerusalem. And during the thousandth year, the number of pilgrims increased. Most of them had sold all their possessions or given them away. Shooting stars or thunderstorms reduced them to panic and prayer.

The end was prophesied for the twenty-fourth of March, 1000, by Druthmar, a monk of Corbie. Terror was so great on that day that the faithful sought refuge in the churches, remaining until midnight before the relics of the saints, in order to die at the foot of the cross. From this period date many gifts to the Church; lands and goods were given to the monasteries.

The end of the tenth century and the beginning of the eleventh was a truly bizarre and fearful period. A widespread and fatal infectious malady, in which the flesh of the victims decayed and fell from their bones, swept through the length and breadth of Europe. Then came years of famine. "The price of a 'muid' of wheat," writes the monk Raoul Glaber in a very curious document, "rose to sixty gold sous; the rich waxed thin and pale; the poor gnawed the roots of trees, and many were in such extremity as to

devour human flesh. The strong fell upon the weak in the public highways, tore them to pieces, and roasted them for food. Children were enticed by an egg or some fruit into byways, where they were devoured. This frenzy of hunger was such that the beast was safer than man. Famished children killed their parents, and mothers feasted upon their children. One person exposed human flesh for sale in the market place of Tournus, as if it were a staple article of food. He did not deny the fact and was burned at the stake. Another, stealing this flesh by night from the spot where it had been buried, was also burned alive."

The end of so miserable a world was both the hope and the terror of that mournful time.

To this critical period in the history of mankind we owe the construction of the magnificent cathedrals which have endured the ravages of time and have excited the wonder of centuries. Immense wealth had been bestowed upon the clergy, which increased its riches by donations and inheritance. "After the year 1000," writes Raoul Glaber, "the holy basilicas throughout the world were entirely renovated, especially in Italy and Gaul, although for the most part they were in no need of repair. Christian nations vied with each other in the erection of magnificent churches. It seemed as if the entire world, animated by a common impulse, shook off the rags of the past to put on a new garment; and the faithful were not content to rebuild nearly all the episcopal churches, but also embellished the monasteries dedicated to the various saints, and even the chapels in the smaller villages."

All chroniclers report on a returning ecstasy of life after a particularly critical period in the history of humanity.

Thus, after the Black Death, there were new fashions in clothes. Marriages became more numerous, increasing the populations of the majority of towns above their former size. Civic life revived, and the remarkable increase of power in France and England, which had been devastated to such a great degree, once again gave testimony to the indestructibility of the human race. If atomic energy is turned to peaceful purposes, we can expect a similar rebirth, in which the world will once more begin to live and joy return to it. And this newly released force will permit man to create a world rich and prosperous beyond all previous dreams.

Though the fatal year 1000 had vanished into the past, the problem of the world's end (though uncertain and vague) remained. Fostered by the belief in prodigies and the devil, it was to endure for centuries in the popular mind where it is still harboured today.

The idea of the end of the world was not confined to the Church alone. In 1186, astrologers terrified Europe by announcing a conjunction of all the planets in the constellation of Libra, the Scales, which indeed occurred. Rigord, a writer of that period, says in the *Life of Philip Augustus*: "The astrologers of the East, Jews, Saracens, and even Christians, sent letters all over the world, in which they predicted, with perfect assurance, that in the month of September there would be great tempests, earthquakes, mortality among men, seditions and discords, revolutions in kingdoms, and the destruction of all thing. But," he continues, "the event very soon belied their predictions."

In 1198, another alarm was raised when it was announced that Antichrist had been born in Babylon and that all the human race would be destroyed. A curious list could

be compiled of all the years it was said that Antichrist had been born; the years might be counted by hundreds.

Arnauld de Villeneuve, the celebrated alchemist, foretold the end of the world for 1335; and on June 15, 1406, an eclipse of the sun produced in France a general panic in which the people took refuge in the churches as if the world were about to perish.

The famous Spanish preacher, St. Vincent Ferrer (1350?-1419) in a treatise called *De la Fin du Monde et de la Science Spirituelle*, allowed the world as many years' duration as there are verses in the Psalms—namely, 2537.

In Germany, Stoeffler, a very celebrated astrologer and one of the most famous European mathematicians, prophesied a great flood, as in the time of Noah, for the year 1524. The prediction was based upon his calculation that Saturn, Jupiter, and Mars would meet in the constellation of Pisces, the Fishes, in February of that year. Everyone in Europe, Asia, and Africa to whom these tidings came, was filled with a sudden overwhelming fear; and as the ominous day approached, the degree of fear and stupidity grew. Trade and commerce stopped. The peasants ceased to cultivate their fields. Work, everywhere, came to a standstill. No debts were paid; and money was spent on riotous living, though some grew the more pious as February drew near and their wet grave loomed close. Thus out of the vanished centuries echoes the hollow voice we hear on every side today: "Why bother concerning oneself with daily affairs when the end of the world is imminent?"

Contemporary authors report that the people of the maritime provinces of Germany sold their lands for practically nothing to those who had more money and less credulity. Some moved to mountain districts in order to

escape the waters, just as some people are moving to the country to escape the Bomb today. Others built themselves boats like arks: a doctor of Toulouse, France, made a huge ark for himself, his family, and his friends. Similar precautions are being taken at present by certain people who are building themselves atomic refuges out of caves, where they will live like our primitive parents.

But February came and went, and no great flood occurred. While a wave of relief swept over the world, the Electorate Castle at Berlin-Cölln on the Spree could not free itself from fear and a dull sense of calamity. The Elector, Joachim I, was informed by his court astrologer, Johannes Carion, that Stoeffler had made an error in his calculations and that the flood would happen on July 15, 1525. Moreover, Carion said that it would not be universal, but be confined to German territory and especially to Berlin-Cölln. This prediction was kept a secret by order of the Elector.

On the afternoon of July 15, 1525, a formidable bank of clouds appeared on the horizon with the following results: the gates of the castle were suddenly thrown open, and a whole procession of state coaches (containing the Electoral family, its ministers and its household, together with the state cashbox) went racing along as rapidly as it could towards a small hill. These proceedings were watched with dismay by the citizens, who were filled with terror when the reason for the extraordinary behaviour became known. Coupled with this terror was fury at the cowardly way in which their sovereign had sought safety without a warning to his subjects.

A little storm broke over the people on their miniature mountain at nightfall; but when the sun broke briefly

through the clouds, the Electress Elisabeth persuaded her companions to go home, where, in the courtyard, a flash of lightning, heralding an approaching storm, killed the postilion, the four horses of the royal carriage, and all but frightened the Elector to death.

Stoeffler, associated with the celebrated Regiomontanus, who probably prepared the tables used by Columbus on his voyage of discovery, undaunted by the failure of his Biblical flood, predicted the end of the world for the year 1588. The astrological prediction was couched in the following apocalyptic language: "The eighth year following the fifteen hundred and eightieth anniversary of the birth of Christ will be a year of prodigies and terror. If in this terrible year the globe be not dissolved in dust, and the land and the sea be not destroyed, every kingdom will be overthrown and humanity will travail in pain."

There were many other predictions of the final catastrophe in the sixteenth century. In 1532, Simon Goulart gave the world a perfectly appalling account of terrible events seen in Assyria: a whole mountain opened and revealed a scroll saying (in Greek), "The end of the world is coming."

The famous astrologer Cyprian Lëowitz predicted a deluge for 1584; it was again a question of planetary conjunctions. Louis Guyon, a contemporary, writes: "The terror of the populace was extreme, and the churches could not hold the multitudes which fled to them for refuge; many made their wills without stopping to think that this availed little if the world was really to perish; others donated their goods to the clergy, in the hope that their prayers would put off the day of judgment."

Nostradamus, the king of astrologers, whose forebodings

are still believed in by many people today, was among the prophets of the sixteenth century. In his book of rhymed prophecies, called *Centuries*, there is the following quatrain:

Quand Georges Dieu crucifiera,
Que Marc le ressuscitera,
Et que St. Jean le portera,
La fin du monde arrivera.

The meaning is that when Easter falls on April 25 (St. Mark's Day), Holy Friday will fall on April 23 (St. George's Day), and Corpus Christi on June 24 (St. John's Day); and the end of the world will come. Camille Flammarion, the popular French astronomer, pointed out that this verse was not without malice, for Nostradamus died in 1556, and the calendar was not reformed until 1582. Before the introduction of the Gregorian calendar, *it was impossible for Easter to fall on April 25*! Easter fell on April 25, its latest possible date, in 1666, 1734, 1886 and 1943. It will again in 2038, so that there is still something to look forward to.

Unusual phenomena, such as comets, eclipses, new stars and shooting stars, also great volcanic eruptions and earthquakes, have frequently been associated with this fear of the end of the world. The announcement of the total solar eclipse for August 12, 1654, produced great alarm. Some believed that it meant the end of the world by fire, others by a new deluge, still others by poisoning of the atmosphere. By the orders of physicians, many locked themselves in cellars, warmed and perfumed. Pierre Petit, a writer of the same century, mentions that a country curate, who was unable to confess all who believed they were about to perish, told his parishioners not to be in such haste, for the eclipse had been postponed for a period of two weeks. His

followers were as ready to believe in the postponement of this great natural phenomenon as they had been in its evil influence.

In the United States, great sects have risen, like those in the Early Church, with the hope and fear of the end of the world as their main source of inspiration, recruitment and income. In 1843, the fear became practically nationwide. William Miller played the chief part in this American drama, a fine account of which has been provided by the writer Geoffrey Dennis.

Miller was a simple man from New England. His only experience in the wider world occurred when he served against Britain in the Canadian War. Then he settled down to farm life in the country, where he became religious and a student of the Prophets, especially of Daniel. It was in the apocalyptic pages of Daniel that the date of the end of the world—1843—was revealed.

Miller's only fear was that he might not have sufficient time to spread the news to those who were chosen, and that the time might be too short for these people to prepare their souls for the day of wrath. It would appear that Miller was a totally disinterested man: wealth, power and admiration were not his desire. He was finally spurred to action by certain rivals: by Harriet Livermore, who was announcing the end for 1847; by Joseph Wolff, of Jerusalem, who was waiting for the end in Jerusalem; and by Captain Saunders, of Liverpool, who was waiting for it in Liverpool. Having asked and been granted permission from heaven, Miller publicly announced his revelation.

Miller determined the date of the end of the world by mathematical calculations based upon the writings of the Bible. The exact day was also revealed. The earth would

cease to exist by midnight on the vernal equinox, or March 21, 1843.

The prediction won a large and immediate following. In a few months the Millerites had become a sect, spreading quickly throughout Massachusetts and beyond. In addition to the believers, there were also exploiters, such as Elder Joshua V. Hines. Hines thought that Miller, a humble *illuminé*, was quite incapable of looking after the business and campaign side of the movement. He launched a large organized campaign: "End of the World for '43." It was a fruitful one; the movement grew, as did the wealth of its leader, Joshua.

The movement also had its enemies. Orthodox pulpits attacked its destructive doctrines; they were harmful to their own. Some people declared that the Millerite house of worship would not be ready for dedication until May, 1843, some weeks *after* the end of the world. It was replied that there was a margin of error for the actual day of the end. Others claimed that the temple was insured for seven years. This was denied. Obviously the Millerites were essentially sincere, for many of them had given away their furniture, sold their farms, cut down their orchards, and abandoned their crops.

Then the comet came. It appeared suddenly in February, approaching the sun with frightful velocity. Behind it, relatively to the sun, stretched a tail about 200,000,000 miles long. It cut the night sky in two and was regarded as the sign indicating the coming of the world's end. New believers came forward. Old believers were irresolute.

Before evening on March 21, 1843, large crowds of men and women moved out from Boston into the open country, to the small hills, from which heaven could receive them

most easily. Thousands of others followed to watch them. As the earth's last darkness fell and the stars came out, the Millerites joined in shouting hallelujahs until midnight. The disorder and uproar were remarkable. Then the hour came—and went. Nothing happened. Through the dawn of March 22, the crowds were seen moving homeward, crushed and silent, or weeping.

In another place, a group of believers waited in white ascension robes, an idea of Elder Joshua V. Hines, though he later denied it. One man attached a turkey's wings to his shoulders and attempted flight. He fell and broke his arm.

At Westford, Massachusetts, the Millerites gathered in their farmhouse headquarters, planning to spend the final evening in prayer and promise. Just before midnight, they intended to move outside for the ascension. Now it happened that Crazy Amos was not a believer; and when the Millerites were all safely indoors, he went secretly to the village green nearby. There he blew a great blast on a great horn, which was his cherished toy. The Millerites heard. In a body, they hastened out of the farmhouse, wildly pushing each other as they fought to secure the best position to be caught up from. Hiding in the darkness, Crazy Amos put his horn to his lips again and again, blowing even more fearful blasts than the first one. "Glory! Glory! Hallelujah!" the Millerites shouted as they raised their arms to heaven. A few of them actually rose into the air; the Second Ascension had begun. But, at that moment, some of the faithful discovered Amos blaring away. The shame, disappointment and fatigue were great; and, as they shuffled indoors, Crazy Amos called after them in derision: "Fools! go dig your potatoes! For the Angel Gabriel, he won't go a-digging 'em for you."

While some of Miller's followers dropped away after the ill-fated day, most of them remained faithful to the movement; for Miller was discovering new dates. The year was all he had ever announced as part of the revelation proper. There were nine months yet during which his prophecy could be fulfilled. Embarking upon a still more intensive study of the Prophet, he at once discovered his mistake. The year was the *Jewish* year, so that the end was for the vernal equinox of 1844.

On the appointed day, new crowds, though diminished in size, went forth to the hills. Again nothing happened. But only when the Jewish year ended and the last hope was gone did the movement disappear. The world did come to an end, however, for old William Miller, who died soon after of a broken heart.

During the meteor shower of November 27, 1872, when the sky seemed to be filled with as many meteors as snowflakes in a snowstorm, it is reported that some women, at Nice especially, as also at Rome, associated these celestial fireworks with the fall of the stars which the Bible foretold would usher in the end of the world. "And the stars of Heaven shall fall, and the powers that are in Heaven shall be shaken," writes St. Mark about that last great event.

The twentieth century is not devoid of its prophets without honour. In 1910, when scientists announced that we would pass through the tail of Halley's comet, there were dire predictions in the Press about poisonous gases that might asphyxiate all life on earth. In the journals of Sydney, Australia, an official warned his townsmen to remain screened indoors on the day it was calculated that the earth would be submerged in the tail.

In 1945, a prophet in California gave the exact day, hour

and minute the world was going to end, according to a vision he had seen seven years before. When the appointed time arrived and nothing happened, he consoled his followers by setting a new date and asking them to wait in patience.

Ever since the announcement of the atomic bomb, people have been asking, like our ancestors before a sudden darkness, a menacing comet, or a violent earthquake, "Is this the end?" The geometric symbols of the atomic bomb glitter like Christmas-tree ornaments in today's illimitable forest, and the ancient malady of fear of the world's end goes forth in every land.

It is true that natural forces of tremendous power have been in existence since the earliest days of man, that they have produced great destruction, but that they have not caused the end of the world. In the reign of Tiberius Claudius Nero Caesar, a terrible subterranean disorder convulsed all Asia Minor and Syria, destroying twelve famous cities in a single night. The setting sun which had gilded their palaces and temples with its parting rays discovered them prostrate at sunrise the following morning.

On August 23, A.D. 79 (as has been mentioned already), Mount Vesuvius, awakening from the slumber of a thousand years, buried the towns of Herculaneum and Pompeii under a deluge of mud and ashes. Never has a volcano devastated a more cheerful paradise than the fields of Campania, or buried more beautiful cities.

The violent eruptions of Mont Pelée on the island of Martinique and the devastation of the entire city of Saint-Pierre is a modern example of the enormous power of hidden forces deep inside the earth's interior. On the awful

day of May 8, 1902, *all the inhabitants, or 30,000 persons, perished, and the buildings suffered total destruction.*

But the wartime application of atomic energy will not just put a few cities in ruins. Never before has a force capable of producing such widespread destruction been in existence upon the earth. A hydrogen bomb *may* blow up our planet, or it may annihilate all life on the earth through radioactive poisoning of the atmosphere. If nothing worse, an all-out war fought with such bombs might mean the obliteration of all the large cities of the world, together with many of the smaller ones, and the death of all their inhabitants.

On the other hand, if atomic energy is turned to peaceful purposes, out of the coming years a Dante, a Michelangelo or a Palestrina may emerge. It is during periods of transition like these that great men and works of art are produced. Important strides are already being made in the science of medicine, and it is expected that the discoveries to be made with the 200-inch telescope will be no less important than those made by Galileo in the seventeenth century. A period of extra-terrestrial expansion is opening; man is finding himself on the very threshold of a new freedom, the freedom to travel beyond the earth's atmosphere and explore the whole universe. The atomic age promises to be an era in which the conditions of life for all human beings will be greatly raised. Affording to every one of us the opportunity to develop and express such capacity as he has for truly human living and truly human work in the great common enterprise of man, the world of tomorrow may be the utopia of which men have so long dreamed.

Two

COMET COLLISIONS

TWO

COMET COLLISIONS

THE MOST ANXIOUS question that has been asked of the astronomer is: How and when is the world to come to an end? It is a question which, of course, the astronomer has no power to answer with truth, but it is one that he has answered frequently in good faith.

It is quite natural to ask such a question of the astronomer, inasmuch as his science deals with the structure and evolution of the universe. These subjects are apt to throw some light on its future. Yet the question has been answered (as was shown in the preceding chapter) by others than astronomers, by theologians on grounds connected with the revelations of the Bible, and by astrologers, whose province it was supposed to be to open the destiny of all things. But today this theological and astrological aspect of the last great day has given place to a modern scientific study of the question.

In the last few years, a new phenomenon is to be noted: the nuclear physicist has been warning that the atomic bomb presents a new kind of a threat to our planet. For the first time in the history of the world, there is a man-made possibility of total destruction. Until the present, there have only been astronomical ones.

The question of the end of the world is one which stands on a very different footing from that which it occupied before the days of Copernicus and Galileo. *Then* it was

believed that the earth was the centre of the universe and that all the celestial bodies were created for it. *Then* the beginning of the world was the beginning of the universe; its end would be the end of everything. *Now* it is known that the earth is one of several planets circling the sun and that the stars are suns with, perhaps, planetary systems like our own. Thus, the destruction of the earth will make no difference whatever to the other celestial objects—still less its becoming uninhabitable. It is an event which probably happened and is happening to other worlds, without influencing the rest of the universe in any marked degree. Nevertheless, for ourselves, the question remains as interesting as if the earth were the centre of the universe, but it must be approached in a different way.

The fear of comets, so vivid in the ancient and early history of humanity, continues to reappear today. But there is an essential difference between the superstitious beliefs of former times and the credulity at present. Formerly every appearance of a comet was looked upon as a supernatural event, a warning from heaven; and natural misfortunes occurring in the days of the comet, such as winds, famines, plagues and the death of kings, were attributed to the passage of the terrible visitor and regarded as so many decrees of Providence. Today a comet is feared because of the popular impression that a collision between it and the earth is a fact which may occur, resulting in the world's end. This is the first astronomical possibility of the end of the world which will be considered.

Imagination makes a mesh. Soaring to immense heights, the threads are drawn out to longer lines than rain, and fall, frequently, from nothing—as was the case in the spring of the year 1773. From one fact—a simple announcement

that Lalande was to read before the Academy of Sciences a paper called *Reflections on those Comets which can approach the earth*—a rumour, soon followed by a strange panic, began in Paris and spread throughout France. The rumour was that the mathematician Lalande had predicted that on May 20 or 21, 1773, a comet would cross the earth's path, collide with the earth, and produce the end of the world.

The title of the paper alone was enough to set men's minds picturing, in detail, a great astronomical catastrophe. What was imagined was absolutely without any foundation, however; nothing like this was to be found in the paper.

The panic excited by the rumour was so great that Lalande, before publishing his work, inserted the following announcement in the *Gazette de France* of May 7: "M. de Lalande had not time to read a memoir on the subject of the comets, which by their approach to the earth may occasion disturbances to it; but he observes that it is not possible to fix the date of these events. The next comet whose return is expected is that which is due in eighteen years, but it is not among the number of those which can harm the earth."

It appears that this notice did not restore peace to the minds of unscientific Frenchmen; for, under the date of May 9, the following is written in the *Memoires de Bachaumont*: "The cabinet of M. de Lalande is still besieged by the curious, anxious to interrogate him upon the memoir in question, and doubtless he will give to it a publicity which is now necessary, in order to reassure those whose heads have been turned by the fables to which it has given rise.

"So great has been the ferment that some *dévots*, as ignorant as they are foolish, solicited the archbishop to have a

forty hours' prayer, in order to arrest the enormous deluge threatened; and that prelate was on the point of ordering the prayer, when some Academicians made him sensible of the absurdity of such a proceeding. The false announcement in the *Gazette de France* has created a bad effect, for it is believed that the memoir of the astronomer must have contained terrible truths, since they were thus evidently disguised."

In France wit never fails to assert its right. Far more effective was the refined irony of Voltaire in his celebrated *Letter on the Pretended Comet.* Dated at Grenoble, May 17, 1773, it ran as follows:

"Certain Parisians who are not philosophers, and who, if we are to believe them, will not have time to become such, have informed me that the end of the world approaches and will occur without fail on the 20th of this present month of May.

"They expect, that day, a comet, which is to take our little globe from behind and reduce it to impalpable powder, according to a certain prediction of the Academy of Sciences which has not yet been made.

"Nothing is more probable than this event; for James Bernoulli, in his *Treatise upon the Comet*, predicted expressly that the famous comet of 1680 would return with a terrible crash on May 19, 1719. He assured us that its wig would signify nothing dangerous, but that its tail would be an infallible sign of the wrath of heaven. If James Bernoulli has made a mistake in the date, it is, after all, but a matter of fifty-four years and three days.

"Now, an error so inconsiderable being looked upon by all mathematicians as of no account in the immensity of ages, it is clear that nothing is more reasonable than to

expect the end of the world on the 20th of the present month of May, 1773, or in some other year. If the event should not happen, what is deferred is by no means lost. . . .

"The Parisians will not desert their city on the 20th inst.; they will sing their songs, and the play of *The Comet and the End of the World* will be performed at the Opéra Comique."

The last touch is as fine in its way as Sydney Smith's remark that, if London were destroyed by an earthquake, the surviving citizens would celebrate the event by a public dinner among the ruins.

Voltaire's prediction was not fulfilled exactly to the letter. But what actually happened was even more preposterous than what the great wit had suggested: the alarm inspired by the end of the world was so great that opportunists took advantage of the terrors of the ignorant, and *seats in Paradise were sold at a very high rate.* It was explained that the priesthood had, by special intercession, obtained the privilege of dispensing a number of tickets. It would be curious to know what idea was held by those who bought the tickets as to the way in which they were to be used, to whom presented, at what time, and where.

In 1832, a scientific announcement once again was wrongly interpreted, giving rise to chimerical fears. In calculating the reappearance of Biela's comet which was to return in 1832, Damoiseau found that it would cut the orbit of the earth on October 29. Nothing more was needed than this detail to produce a panic. The papers said that our globe, violently struck, would be shattered to pieces, that the end of the world was evidently at hand.

One important point alone had been forgotten. Arago, the celebrated French astronomer and physicist, after concluding that a portion of the earth's orbit would be

covered by the nebulosity of the comet, set people's minds at rest by alluding to this point as follows:

"There remains but one more question, which is this: at the time when the comet is so near our orbit that its nebulosity will envelop some portion of it, *where will the earth itself be situated*?

"I have already said that the passage of the comet very near to *a certain point* of the terrestrial orbit will take place on the 29th of October, before midnight; the earth, however, only arrives at this point on the morning of the 30th of November, that is to say, *more than a month later*. We have, then, only to remember that the mean velocity of the earth in its orbit is 1,675,000 miles per day, and a very simple calculation will suffice to prove that the comet of six and three-quarter years period will be, at least during its apparition in 1832, *always more than 49 millions of miles from the earth*!"

In 1857, fear of the end of the world was current in Europe again. A fantastic prediction, this time coming from Germany, told of how the world was to be destroyed by fire, burned by the comet of June 13, 1857. The prediction at first related to the collision with an imaginary comet. But, with the serious expectancy with which scientists awaited the return of the comet of 1264 and 1556, the future catastrophe was attributed to the returning comet. Nothing, however, in the orbital elements of the comet of 1264 justified such a collision.

The terrors of the years 1773, 1832 and 1857 create a smile today. But similar fears, as in 1910 with Halley's comet, have been renewed from time to time in our own century.

The opinions of early scientists respecting the effects of a

collision between a comet and the earth are curious. One of the strangest theories in the annals of science is the theological romance invented by Whiston, an Englishman and a contemporary of Newton, for the explanation of the Deluge. The theory is described in some detail here because of its interesting similarity between the work of Immanuel Velikovsky, which recently created such a tremendous and widespread controversy, and because of its celebrity in science.

In 1696, Whiston published *A New Theory of the Earth*, in which the theologian-astronomer explained, by the action of a comet, the geological revolutions recorded in the book of Genesis. His theory was at first hypothetical; it was not framed with respect to any particular comet. But when Halley assigned an elliptical orbit with a period of 575 years to the comet of 1680, and when Whiston identified the dates of two of its former appearances with two of the years fixed by chronologists as the date of the Mosaic Deluge, he stated his theory more precisely, making the comet of 1680 appear as not only the destroyer of the human race by flood, but also as the destroyer of the world by fire in future ages.

According to Whiston's theory, the earth is an ancient comet whose perihelion (the point in the orbit of a celestial object where it is nearest the sun) was originally very close to the sun. The great temperature to which the comet was subjected at each of its perihelion passages explains the central heat of the earth. When the earth was to be rendered habitable, one operation alone was sufficient: the centrifugal force (the reaction of a body against a force that is causing it to move in a curved path) of the comet was diminished; and its orbit was thus made less eccentric, so

that the globe's perihelion was not as close to the sun. This change caused the thick atmosphere of the ancient comet to become purified and the air, the soil and the water to gradually find their equilibrium. The sun and the moon looked down upon the earth, and man and beasts appeared.

When man had sinned, Whiston said, a small comet passed very near the earth and, cutting obliquely the plane of its orbit, gave the earth a motion of rotation. (No doubt this was the comet which supposedly produced the perfect circularity of the terrestrial orbit which, according to Whiston, existed before the Deluge.) God had foreseen that man would sin and that his crimes would demand a terrible punishment; consequently He had prepared from the moment of creation a comet to be the instrument of His vengeance. The comet was that of 1680, and the catastrophe was accomplished in the following manner.

On November 28, 2349, or December 2, 2926 B.C., the comet, to which Whiston assigns a mass equal to a quarter of the earth's mass, cut the plane of the earth's orbit at a point 9,000 miles from our globe. The meeting happened at noon under the meridian of Peking, where Noah was dwelling before the flood. The effect of this meeting was to produce a huge tide, not only in the waters of the sea, but also in those underneath the solid crust. The mountain chains of Armenia, which were nearest to the comet at the moment of conjunction, were opened and shaken to their foundations, and thus "were all the fountains of the great deep broken up." The disaster did not stop here. The coma and tail of the comet, coming into contact with the earth and its atmosphere, discharged an immense quantity of aqueous particles, enough to produce forty days of rain;

and thus "the windows of heaven were opened." According to Whiston, the depth of the waters of the Deluge was about $6\frac{1}{4}$ miles.

Whiston also explained how the comet, which the first time drowned nearly all the living beings on the earth, will cause the destruction of the earth's inhabitants by fire at a second encounter. Arriving behind us, the comet will retard the motion of our globe and change its orbit into a very eccentric ellipse. The earth, at the time of its perihelion passage, will be brought very near to the sun; it will experience an intense degree of heat; it will be consumed.

The comet may have a direct action as well: it may strike the earth. It is known that the comet of 1680 approaches very near to the surface of the sun, so that, following Pingré's summary of Whiston's views, "hardly can the mouth of a volcano vomiting forth lava liquefied by the interior consuming heat give an idea of the fiery atmosphere of this comet. The air will then interpose no obstacle to the activity of the central fire; on the contrary, the inflamed particles with which our atmosphere will be charged, carried down by their own weight into the half-open bowels of the earth, will powerfully second the action of the central fire. This comet might even separate the moon from the earth, and affect the diurnal and annual motion of the earth by rendering both these movements equal, and by destroying besides the eccentricity of the terrestrial orbit, which would again become circular as before the Deluge. Lastly, after the saints have reigned a thousand years upon the earth, itself regenerated by fire, and rendered habitable anew by the Divine will, a comet will again strike the earth, the terrestrial orbit will be excessively elongated, and the earth, once more a comet, will cease to be habitable."

Whiston, a man of great erudition and science, shared the fault of his time: he tried to make his ideas accord both with theology and astronomy. Considering only the scientific side of the question, it is certain that Whiston's theory is untenable. No astronomer would admit as possible the enormous mass we are compelled to assign to the comet of 1680. Even assuming such a mass, its action would be of so short duration, because of the relative velocities of the comet and the earth, that the supposed effects would not have time to occur. These are only two vital objections; others could be added, and from the standpoint of other sciences as well.

In 1950, a very controversial book, *Worlds in Collision*, by Immanuel Velikovsky, made its appearance, creating as much excitement as the apparition of a great comet. This book bears a striking resemblance to Whiston's *A New Theory of the Earth*, published some 250 years ago. Velikovsky, like Whiston, attempts to explain certain events in the Bible by cosmic catastrophes (the Deluge is to be the subject of another volume). Both authors maintain that comet collisions were responsible for terrestrial cataclysms; both authors believe that comets became planets; both authors support their theories by evidence from historical texts, traditions and legends of many countries. As in *A New Theory of the Earth*, the science of Velikovsky's work is completely untenable; it was so over a century ago and still is today. For this reason, there is no point in describing these ideas here at any greater length.

In the middle of the eighteenth century, theological speculations engaged the attention of astronomers only slightly; but a very exaggerated idea continued to exist regarding the amount of damage which the proximity of a

comet or its collision with the earth would be capable of producing. Maupertuis, the author of *Lettre sur la Comète*, believed that a comet could break the earth into a thousand pieces; both bodies would be destroyed, but from the fragments gravity would speedily form one or more new planets. Maupertuis, it would seem, was of the same way of thinking as certain amusing people who regard catastrophes of the most formidable kind as matters for calculation and opportunities for the furtherance of scientific knowledge.

In his *Lettres Cosmologiques*, Lambert wrote that the near approach of a comet might bear the earth off into the region of Saturn, compelling it to endure a winter of several centuries, which neither man nor animal would be capable of resisting.

Although Laplace considered the probability of a comet collision as extremely slight, and although he believed that cometary masses were so small that only local disturbances would be produced, still he depicted the effects of a meeting, on the supposition that the mass of the comet was comparable to that of the earth.

"The axis and the movement of rotation would be changed," the great mathematician wrote in *Exposition du Système du Monde*. "The seas would abandon their ancient positions, in order to precipitate themselves towards the new equator; a great portion of the human race and the animals would be drowned in the universal deluge, or destroyed by the violent shock imparted to the terrestrial globe; entire species would be annihilated; all monuments of human industry overthrown; such are the disasters which the shock of a comet would produce, if its mass were comparable to that of the earth."

Laplace, moreover, did not seem far from believing that

such a cataclysm had taken place. The geological revolutions, which contemporary geologists tended to refer back to a not very distant date, appeared to him capable of being explained by such an event. "We see then, in effect," he continued, "why the ocean has receded from the high mountains, upon which it has left incontestable marks of its sojourn. We see how the animals and plants of the south have been able to exist in the climate of the north, where their remains and imprints have been discovered; in short, it explains the newness of the moral world, certain monuments of which do not go further back than five thousand years. The human race reduced to a small number of individuals, and to the most deplorable state, solely occupied for a length of time with the care of its own preservation, must have lost entirely the remembrance of the sciences and the arts; and when progress of civilization made these wants felt anew, it was necessary to begin again, as if man had been newly placed upon the earth." Today Laplace would toss this explanation of the geological facts of past times in discard. Modern science has since interpreted these facts very differently.

At present there is a tendency on the part of some astronomers to laugh at comets and regard them as visible nothings. This, however, is the other extreme, as the following discussion will demonstrate.

It is now believed that comets are and always have been members of the solar system. They seem to be newly created objects only because they travel around the sun in immense paths, which do not permit frequent observation of them.

Comets, in so far as shape is concerned, are the jellyfish of the sidereal ocean. The globular-like part of that marine

animal might be compared to the *head* of a comet, while the stingers, which go out behind, resemble the *tail*. The head usually consists of two parts, the *coma*, a large nebulous body, and the *nucleus*, a bright, starlike point near the centre of the coma. Composed primarily of particles of stone and metal of a great variety of sizes and widely separated from each other, the head of a comet is also made up of gases and very fine dust, which are the main constituents of a comet's tail.

Since many comets cross the earth's orbit, the collision of the earth with a comet is not at all impossible. In fact, it has been computed that *the nucleus of a comet which comes within the earth's distance from the sun stands about one chance in 400,000,000 of hitting the earth.*

The significance of the numerical result can be illustrated in the following manner. Imagine an urn containing a total number of 400,000,000 balls, only one of which is black. Also imagine, for a moment, that if a comet were to strike the earth with its nucleus, it would annihilate the whole of the human race. In that case, the danger of death to which each individual would be exposed by the apparition of an unknown comet would be exactly equal to the danger he would incur supposing that his condemnation to death were the consequence of his picking the black ball at the first drawing.

This is a trifling danger indeed. It is even more so when we consider that such a collision could result in local ruin only and that the chances of a comet's falling on a thickly populated area are not great. For three-quarters of the earth's surface is covered with water, and the land area is not entirely inhabited. Yet the moment that a comet is announced, before it has been observed or its course

determined, it is for many individuals of our globe the black ball of the urn.

Although the probability against a collision is so great, we need not entirely despair! As about five comets come within the earth's distance from the sun each year, it can be computed that a comet's nucleus should strike the earth, on the average, once in approximately 80,000,000 years. Accordingly, during the earth's 2,000,000,000 years of existence, our planet must have undergone some twenty-five collisions.

Encounters of the earth with the outer parts of the head should be much more numerous, while passages of the earth through the tails of comets are probably of frequent occurrence, since the tails are of such tremendous size.

The mass of comets appears to be only a small fraction of the mass of the terrestrial globe. For when comets pass near the planets, they do not cause any great disturbance in the planets' motions, nor even in those of their moons. On the other hand, comets have been so much disturbed during these approaches that the shape and period of their orbits have been changed entirely. In 1770, Lexell's comet made the closest observable approach of all comets to the earth, coming within a distance of approximately 1,500,000 miles, or about six times the moon's distance from the earth. As a result, its revolutionary period was changed by two and a half days by the earth's gravitational effect. According to the American astronomer Russell, if the comet's mass had been 1/13,000 the earth's, our year would have been altered by this close approach by the amount of one second. If the mass had been equal to the earth's, the earth's orbit would have been changed and made larger, so that our year would have become two

hours and forty-seven minutes longer than it is. But no such result took place.

Lexell's comet was calculated to return in 1776, but *it was never seen again.* Investigators, taking up the problem, discovered that in 1767 and 1779 this comet had passed very close to Jupiter; and it was decided that its orbit was so greatly modified by the giant planet that it had become a "lost comet."

During the 1779 approach, the comet passed between Jupiter and some of its satellites; but the moons did not have their revolutionary periods changed by this experience, the significance being that the comet must have had a mass less than 1/5,000 that of the earth.

While the mass of comets is small as compared with that of the earth, these objects are not such "airy nothings" that one could be packed into a suitcase, with room left over to spare. This idea of some individuals is entirely erroneous and most absurd. Authorities estimate that comets are not more than 1/1,000,000 as massive as the earth and that most of them have masses much less than this. Yet, even, with the above figure, a comet would weigh 6,000,000,000,000,000 tons.

If a comet were of average size (80,000 miles in diameter) and had a mass equal to 1/1,000,000 that of the earth, the average density would be 1/1,230,000 of that of the air at the earth's surface. This degree of rarefaction is reached only by the best air pumps. The low density of comets is indicated also by two phenomena: first, stars are seen usually with undiminished lustre when a comet passes over them, and often right near its nucleus; second, comets become absolutely invisible when they pass across the face of the sun. The density of a comet's tail is vastly less than

that of the coma or nucleus. It should be kept in mind, moreover, that the low average density of a comet does not necessarily mean that the density of its constituent parts is small, but that the solid particles of which it is largely composed are scattered over a large cubic space.

As to the consequences of the collision of the head of a comet with the earth, everything depends upon the size of the solid particles which compose it and which form the main portion of the comet's mass. If they weigh tons, the bombardment experienced by the earth when struck by the comet would be disastrous, although it most likely would not result in the total destruction of terrestrial life. If the particles were for the most part as small as grains of sand, the result would be simply a magnificent display of shooting stars.

Meteor Crater in Arizona, declared to be the most interesting spot on earth by Svante Arrhenius, the great Swedish scientist, can be described as an example of the danger of the collision of a swarm of meteors, or a comet, with the earth. H. H. Nininger, one of the leading authorities on meteoritics (the systematic study of meteorites, meteors and associated phenomena), has recognized portions of a large number of different meteorites around the crater; and since a comet is in the nature of a swarm of meteors (solid particles of a great variety of sizes widely spaced from each other), together with gases and very fine dust, it can be said that, at the time the great crater was formed, a comet struck the earth.

The proof of this great disaster, which occurred 20,000 to 50,000 years ago, can be seen in Coconino County, in north-central Arizona, about twenty miles west of Winslow and thirty-five miles east of Flagstaff. The crater is reached

easily by the Santa Fé Railroad or by U.S. Highway 66.

This spectacular topographic feature is 4,000 feet in diameter, with walls rising 150 feet above the surrounding plain and descending 600 feet precipitously to the floor. The Washington Monument, if set on the centre of its floor, would not reach to the height of its rim; and if its walls were furnished with benches, like a great athletic stadium, it could accommodate 2,600,000 spectators. This would still leave room on its central floor for several football fields.

The amount of solid rock shattered or heaved aloft by the collision is estimated at over 300,000,000 tons; and although the floor is only 600 feet deep, investigations reveal that the real bottom of the crater reaches a depth of 800 feet below this level. That is, the true crater is filled to over half with rock fragments which rolled or fell back.

For over half a century, men have hunted for the principal mass which was mainly responsible for the crater and which was thought to be buried at the bottom of the scar in the rock-ribbed desert. Recently, however, evidence was found that the remains were under the very feet of the searchers. Thousands of millions of tiny nickel-steel particles, no larger than salt crystals, were found mixed with the soil about the crater.

It is now believed that the energy of onward motion, when the comet struck the earth, was transformed into sufficient heat to vaporize the main body and the material it encountered. There must have been a violent explosion, shattering the surrounding rock strata and hurling it skyward. The cloud of metallic vapour from the vaporized body must have risen miles into the atmosphere; and, as the metallic vapour cooled and condensed, the nickel-steel particles formed and rained down upon the landscape.

On June 30, 1908, a group of large meteors struck the forested wastes of northern Siberia. A sound was heard louder than that of thunder, and a column of fire and smoke shot skyward and spread in all directions as dark clouds. At the place of the fall, trees were knocked down and scorched as if by a giant blow-torch—their tops pointing fanlike in every direction from the centre where the great impact had occurred. The scorching effect was visible for ten miles out from the centre, and trees were broken to a distance of fifteen miles.

A farmer living fifty miles away was hit by a heat wave which he feared would set fire to his clothing. He was next knocked unconscious by a great explosion; and upon regaining consciousness, he found his house destroyed. In another locality 1,500 reindeer were killed. And in still another a train had to be stopped because of earth tremors which nearly derailed it.

Some 200 craters were found within a radius of one mile; and from the number and character of these craters, Professor Kulik of the Russian Academy of Sciences estimated that the total weight of the material was about 40,000 tons.

On the date of the Siberian catastrophe, the earth was within 2,790,090 miles of the Pons-Winnecke comet, and there is reason to believe that the meteors were fragments of it. Had the event happened in one of the great metropolitan centres, such as New York City, the destruction to life and property would have been appalling.

In 1950, a titanic new crater was discovered on the barrens near Hudson Bay. The Chubb Crater, as it is called, is 1,350 feet deep, two miles in diameter, and is believed to have been smashed out of solid granite between

3,000 and 15,000 years ago. If it is conclusively shown to be meteoric in its origin, Chubb Crater replaces the well-authenticated Meteor Crater in Arizona as the world's largest.

These craters, formed by the fall of solid particles, such as compose the heads of comets, are dramatic proof of the danger of a comet striking the earth.

A danger of a different kind has been suggested—that if the earth should pass through a comet's tail, there might be a mixture of some deleterious gas in our respirable atmosphere and a general poisoning of the human species. The presence of carbon monoxide, which has been used for so many murders and suicides, and cyanogen, also a very poisonous gas, have been detected in comets. However, because of the low density of cometary matter (Watson states that each molecule of gas is separated from its nearest companion by several miles), it is believed that there is nothing to fear from passing through a comet's tail.

Since several highly inflammable gases (hydrogen and methylene) have been detected in comets, the thought occurs that if the earth were immersed in a comet's tail, a spark might cause the whole incumbent mass of atmosphere in which we exist to burst at once into a species of intense flame. Again, however, the very low density of a comet would appear to prevent such gases from doing any mischief to the earth's inhabitants.

Moreover, fear is allayed by the knowledge that in several instances the earth did pass through the tail of a comet without any harm coming to the human family. On Sunday, June 30, 1861, the earth was plunged in the large tail of the great comet of that year. The reply to the question, were any special phenomena observed which could be attributed

to this meeting, is probably to be found in a letter written by the English astronomer Hind to the editor of *The Times*.

". . . on Sunday evening," he writes, "while the comet was so conspicuous, in the northern heavens, there was a peculiar phosphorescence or illumination of the sky, which I attributed at the time to an auroral glare; it was remarked by other persons as something unusual, and considering how near we must have been on that evening to the tail of the comet, it may, perhaps, be a point worthy of investigation, whether such effect can be attributed to our proximity thereto. If a similar illumination of the heavens had been remarked generally on the earth's surface, it will be a significant fact."

Mr. E. J. Lowe, of Highfield House, near Nottingham, confirmed Hind's statement of the peculiar appearance of the sky. The following note appears in the journal of this savant: "June 30: A singular yellow phosphorescent glare, very like diffused Aurora Borealis, yet being daylight such Aurora would scarcely be noticeable."

This brightness of the sky was probably produced by the fact that the observers were looking into the bright stuff of the comet's tail, which enveloped the earth. On the other hand, since both observations were made in the same country, it might have been some local meteorological phenomenon.

Mr. Lowe also mentions that at the time of the illumination of the sky, the sun gave but feeble light. He says that in the parish church the vicar had the pulpit candles lighted at seven o'clock (during sunshine), which proves that a sensation of darkness was felt. It may be that the gases and dust of the comet's tail were responsible for obscuring the light of the sun.

Another instance of the earth's passing through the tail of a comet is that of Halley's comet in 1910.

Astronomy, as we have seen, teaches that we do not need to fear comets—because of their small chance of colliding with the earth and their small masses. Should the head of a comet strike the earth, however, the event could be disastrous if it took place in a great city, smashing it into a Meteor or Chubb Crater.

Three

MOON, ASTEROID AND STAR COLLISIONS

THREE

MOON, ASTEROID AND STAR COLLISIONS

COMETS ARE NOT THE only objects which may wreak havoc with the earth by collision. According to one astronomical theory of the end of the world, the moon, by its close approach, may bring on a second deluge in the remote future. The following is humbly submitted by the author as a modern paraphrase of that part of the Bible which deals with the Deluge:

In the year of A.D. 50,000,000,000+, a flood of waters will be upon the earth. And both uncivilized man, whose actions do not lend themselves to survival with the others, and beast, together with the creeping things and the fowls of the air, will be destroyed.

Long before this day arrives, mankind will make himself an ark of thin sheet steel. The ark will be in the nature of a system of space ships. Compartments will be made in the ark, and its seams will be coated with solder.

And this is the fashion in which man will make it: the ark will resemble a compact sphere, for this form is most suitable for flight beyond the atmosphere. And the sphere will be driven by the same energy which activates the stars, which is sub-atomic.

A porthole will be made in the ark, and a space hatch; and there will be lower, second and third decks.

The moon, even the moon which at present is ornamental and useful, will bring this flood of waters upon the earth. It will do this by approaching the earth and causing great tides.

But man will come into the ark, and two of every sort of desirable animals will be brought into the ark, to keep them alive with him; they will be male and female.

Of the vegetable kingdom, every desirable plant will be represented in the ark and will be transported, with the whole population of the earth, and with the beasts and the fowls and the things that creep, to another world.

For regardless of what other animals and plants are to be found on the planets, man will want to preserve those which are beneficial on earth.

When the moon approaches the earth, the tides of the moon will rise to enormous heights and at intervals of a few hours will sweep over the surface of the earth, engulfing most of the land surface in their progress. And the ark will be lifted up above the earth by the energy deep within the atoms.

And all the high hills that are under the whole heaven will be covered. And all the flesh that moves upon the earth will perish.

But those who are in the ark will remain alive. The keel of the ark will cut silently the waters of the sidereal sea, and after the end of many days, it will rest upon the shore of a new world.

Then man will open the porthole of the ark which he had made. But he will not send forth a dove or a raven, to test the habitability of the planet. For the new earth will be a known and explored world.

Man will go forth from the ark, bringing forth every living thing that is with him. And the animals will breed abundantly and be fruitful and multiply upon the new world.

And man will build an altar to the Lord, and he will bless the Lord.

This is the way in which the prophecy will be fulfilled.

Most people take it for granted that the length of the day —the period of time against which our clocks are regulated

—is constant. It has been discovered, however, that the day is lengthening slowly—at present, at the rate of one second in about 120,000 years. The change is produced by the friction of the tides, which act as a brake upon the earth's rotation. Since the earth turns on its axis eastwardly, the tides move round the earth westwardly. For the same reason the sun and moon appear to rise in the east and set in the west.

Thus a high tide under the moon (which is the main cause of the tides) on the east side of the Atlantic Ocean travels westward across the ocean, until it meets the continents of North and South America and the land masses of the West Indies. At this time, since the earth rotates in the opposite direction to that of the motion of the great mass of water composing the tidal bulge, it tends to check the rotation of the earth. It appears that today more than two-thirds of this braking action, or tidal friction, occurs in Bering Sea, west of Alaska. There the water is shallow and the tidal currents are strong.

A secondary result of the tidal friction is that the moon is moving away from the earth slowly—at present, at the rate of 5 feet per century. The earth and moon make a unified system, and it has been shown that the total angular momentum (the rotational and revolutionary energy) within a system cannot be changed. Angular momentum can be transferred from one body to another in a system, but it cannot be destroyed.

This is what is happening in the earth-moon system: the angular momentum of the earth's rotation is being transferred into the moon's angular momentum of revolution, with the result that the moon's orbit is becoming larger. Consequently, the moon is gradually receding from the

earth, and the length of the month (the time of the revolution of the moon around the earth) is slowly increasing.

These changes due to tidal friction have been going on for thousands of millions of years. Attacking the problem in the reverse sense, the amazing conclusion is reached that the length of the day was originally 4·8 hours. At that time, the moon's distance from the earth was 9,000 miles; and it revolved round the earth in a period of 4·8 hours, so that the month was equal to the day. Now, the day has lengthened to 24 hours, the month to about four weeks (27⅓ days); and the moon has receded to 238,840 miles.

It is believed that the rate at which the day is lengthening was more rapid in the past than at present and that the moon fled swiftly away from the earth in the early stages. For when the moon was nearer the earth, the tidal effect produced by the moon must have been very much greater. Dr. Ralph Baldwin, in *The Face of the Moon*, estimates that the moon reached half its present distance in about 10 per cent. of geologic time. Since the Cambrian period, which began the last quarter of geologic time about 500,000,000 years ago, the moon, according to Baldwin, has withdrawn only about 18,000 miles; the month has increased by only 3·3 days, and the day has lengthened by about one hour. Almost all the startling changes took place in the first quarter of geologic time, when there were no astronomers to observe them.

Sir George H. Darwin, the son of Charles Darwin, the naturalist, first called attention to the fact and effect of tidal friction; and it was he who proposed the idea that the moon once formed part of the earth. According to his theory, the earth's rapid rotation and the disturbances from solar tides resulted in monstrous tidal bulges, one of

which broke off to form the moon. However, Harold Jeffreys, the English astronomer, found that the tidal and rotational forces were never sufficient to have detached the moon from the still-liquid earth; and it is probable that, although they were born nearly in contact and at the same time, the moon and earth have always been separate.

In the future, tidal friction will continue to slow up the earth's rotation and to cause the moon to move away from the earth, until the month is equal to the day. It is found that this condition will arise in the year A.D. 50,000,000,000, at which time the day and the month will be equal to 47 of our present days and the moon will be about 340,000 miles away. Assuming that the sun is still shining, there will be long, scorching days and long, frigid nights. The day, such as we know it, will no longer exist, and our present clocks will for a long time have tolled only a fantasmal hour. The moon will appear smaller and fainter in the sky, and it will no longer be able to cover the disk of the sun at the time of an eclipse. Consequently, total solar eclipses will be a thing of the past; solar eclipses will all be "annular," with a ring of the sun's surface visible around the dark moon.

Another interesting situation will arise. When the month and day are equal, the earth will keep the same side towards the moon, and inhabitants on that side will always have the moon in their sky. Inhabitants of the earth's other hemisphere will have to make a journey round the world in order to see the moon. An approximation of this condition can be found in the solar system today. The revolutionary period of Deimos is nearly equal to the rotational period of Mars, and the satellite's movement in the sky keeps almost equal pace with the daily motion of the Martian observer.

At this time, there will be a high tide on the earth under

the moon as well as one on the opposite side of the earth. But these will not change position, with the result that there will be no more tidal friction produced by the moon, which will stop receding.

The solar tides, however, which also retard the earth's turning, will continue to operate, providing that the liquid oceans still exist. The earth's rotational period will then be longer than the moon's revolutionary period, and the moon will rise in the west, travel across the sky in a few of our present months and set in the east. Phobos, the inner satellite of Mars, behaves in a similar manner at the present time. Its revolutionary period is so short that it circles Mars three times while the planet is spinning once on its axis.

When the earth's rotation is slower than the moon's revolution, the friction of the lunar tides will again become effective, but its effects will then be reversed. The earth's rotation will now be accelerated, and the moon will be brought closer. This process will continue until the moon comes within a distance of our planet so short that it will be shattered by the gravitational strains imposed on it by the earth's attraction.

This conclusion is based upon a theory of Edouard Roche, a French mathematician, who, in 1850, calculated that if a satellite were nearer to its planet than a certain limit it would be disrupted by tidal forces. For a satellite having the same density as the planet, the limit is 2·44 times the planet's radius. Since the earth is denser than the moon, the limit is 2·86 radii, or about 11,000 miles.

It is interesting that the outermost part of Saturn's ring system is within Roche's limit. This suggests that Saturn's rings are a preview of the moon in thousands of millions of

years to come—that the myriads of separate particles composing the ring system are the debris of a former satellite that moved in an orbit too close to the planet. Seeing Saturn in a telescope is a truly wonderful experience. One has such respect for the planet, with its incomparable encircling rings. There is a marked difference in the appearance of Saturn's rings from time to time, however. Twice during the planet's revolutionary period of thirty years the rings are at such an angle as to present a side view of considerable width; and twice the rings give an edgewise view to the earth, at which times they are invisible. Similarly, when the sails of a boat are glimpsed edgewise out at sea, they appear as only a thin line or are invisible. But when the ship changes its course and presents a broadside view of the sails, they are seen in their greatest visibility.

With respect to Roche's limit, it is interesting to note that Phobos is just outside the danger zone. Assuming that Phobos has the same density as Mars, it can be calculated that Phobos would be torn to pieces if it came within a distance of 5,207 miles. The present distance of the satellite is 5,830 miles. If adequate tidal friction is still operative on Mars, which is unlikely because of the present absence of seas, and if Phobos is approaching and not receding from the planet, it would seem that a great celestial catastrophe is imminent.

It will take our moon about 50,000,000,000 years to reach its maximum distance from the earth. How long it will take to return has not been ascertained. But when the moon does return, the thread of life will be broken, though the fishes in the great seas will survive; and perhaps evolution, proceeding through them (as it did once before), will give rise to higher life forms. As the moon approaches

Roche's limit, the human race, if it has contrived to live so far, will see it violently distorted in the sky. If the astronomer Jeffreys is correct, at a distance of 20,000 miles, the solid substance of the moon will give way, and the moon will acquire an elongated form. The metamorphosis will continue until the largest diameter of the moon is about twice the shortest, at which time the moon will definitely break up, becoming two or more separate satellites, then about a thousand pieces. Coming into collision when they get close to the earth, these fragments will break up further; and myriads of separate particles, forming a ring such as we see encompassing Saturn, will merrily dance a funeral dirge around the lifeless world. Thus, the moon, dead and transfigured, will form an arch of light and bridge of moons across the nocturnal sky. The moon is ornamental now—a round shield of pure silver. But its destruction will transform it into something glorious: it will be one of the finest spectacles in the solar system.

But there will be no men on the earth to enjoy it. The earth will not remain unscathed during the catastrophic progress of the moon. The same unleashed forces that destroyed the moon will disrupt the earth; and as these forces begin to be felt, man will build himself an ark and transport the whole population of the earth to another world. The earth will be deserted, except by the beasts of the field and perhaps some men hiding out in remote regions.

As the moon moves in closer, constantly accelerating in speed, always growing larger and brighter, the earth will experience a series of violent earthquakes. All creatures living or burrowing in the ground, such as mice, rats, moles and snakes (or else the different forms into which they have evolved), will hasten forth from their underground dwell-

ings, though many will be gripped and suffocated by the suddenly moved soil before they can escape. The silent crocodile will rush out of the water and run bellowing into the woods. Hogs will be uneasy; horses will tremble; oxen will huddle together; fowls will run about with discordant cries. Volcanoes will open to extrude the material from the interior of the earth, while the vibrations of the earth's crust will level mountains to ocean floors and raise continents that will be nameless for the want of those who name things. All this will be the beginning of the end.

When the lunar fragments collide, some of them will fall upon the earth as giant meteors, possibly as large as little planets. Thus a portion of the moon will be crushed up into falling stars, which will appear to be as numerous as the drops of rain in a tropical shower. Long before the moon comes within Roche's limit, however—if the oceans still exist—the lunar tides will rise to gigantic heights and, at intervals of a few hours, will rush over the earth's surface, drowning the already ruined cities under miles of dark blue water. Perhaps the only areas safe from the devastating tides will be the mountain peaks.

Thus the moon may bring back the universal deluge. But the oceans may freeze before the moon reaches the danger zone, in which case the tidal friction will almost cease and the process will stop. According to modern theories of stellar evolution, the sun will die in about A.D. 10,000,000,000, so that the death of the sun and the freezing of the oceans may intervene and lock the moon in its orbit. This would be in accord with the promise made in Genesis, where it is written, "And I will establish my covenant with you; neither shall all flesh be cut off any more by the waters of a flood; neither shall there any more

be a flood to destroy the earth." However, the ideas of science are changing continually. And it may be that just when the sun is supposed to stop "burning," a new theory will be invented, and the sun will continue to shine. Meanwhile, in the shallow seas, the tidal friction grinds slowly and inexorably to make the moon fall upon the earth in a far-off time.

Beyond the orbit of Mars, in a great circular belt over 340,000,000 miles wide, another danger lurks: the asteroids, or minor planets, some of which might come into collision with the earth at almost any time. While the menace from the moon might become a reality and result in the complete annihilation of terrestrial life, the effect of an asteroid collision would be local only.

One of the world authorities on the asteroids, Professor Leuschner of the University of California, estimates that there are about 50,000 of these little planets moving silently beyond the earth, and that about 5,000 of them have been observed at one time or another. Of these, there are about 1,600 whose orbits are so well known that they can be found again. The rest have been lost.

Asteroids are of exceptionally small size, as far as terrestrial standards are concerned. The largest four are Ceres, 480 miles in diameter, Pallas, 304 miles, Vesta, 240 miles, and Juno, 120 miles, while the smallest ones visible are less than a single mile across. Probably thousands of them yet unseen are no larger than big rocks.

While most minor planets are confined between the orbits of Mars and Jupiter, an occasional one goes beyond the outermost boundary or within the innermost limit,

sometimes coming in near-collision with the earth. Amor, discovered in 1932, came within 10,000,000 miles of the earth. Its path lies entirely outside that of our planet. In the same year, Apollo, whose orbit comes within that of Venus, was within 6,500,000 miles of the earth. The next record for a close approach was set by Adonis in 1936, when the planet came within 1,500,000 miles of ours. But the record is held at present by Hermes, which, in 1937, came within 485,000 miles of the earth—or about twice our distance from the moon!

Because of the tiny size of the asteroids, it would appear that one which comes within the earth's distance from the sun stands a very much smaller chance of hitting the earth than the nucleus of a comet. Moreover, since most of the asteroids are confined between the orbits of Mars and Jupiter, and since only a few have paths that are at times inside the orbit of the earth, the chances of an asteroid encounter are practically non-existent.

But if an asteroid did strike the earth, the results would depend upon the size, the velocity, and the point of landing of the celestial missile. The diameter of Hermes is believed to be about one mile, while its mass is estimated at 3,000,000,000 tons. When it was nearest to the earth in 1937, its speed was several miles a second. If Hermes had landed at the site of a large city, the damage would have been frightful. The planet would have sunk into the surface a distance of many feet. Kinetic energy of the object, due to its terrific velocity and mass, would have been so large that Hermes would very likely have become vaporized from the heat generated by impact. If the planet had hit Manhattan Island, in addition to the direct destruction, the heat developed by the passage of the mountain mass

through the air would have ignited all buildings for miles around. On the other hand, if the planet had landed in the Atlantic Ocean, an immense "tidal wave" would have been set up, overrunning the low-lying land within reach and dashing to pieces and carrying off everything in its path. Probably, therefore, the best place we could hope for an asteroid to land on the earth would be an uninhabited region of dry land. Earthquake waves would be produced; and by seismograph records, the point of landing of the planet would be revealed. Some astronomers believe that Meteor Crater in Arizona might have been made by collision with a small asteroid.

A huge globe of incandescent gases is hurtling through space at nearly 50,000 miles an hour. In its course, this star has moved unhindered for 2,000,000,000 years. But on this fateful day, a terrible accident is to occur.

Out in the distance ahead looms the sun, which appears to swell out gigantically. The invading star's course is such that there will be a head-on collision. Coming more and more under the gravitational influence of each other, the two stars move towards the same spot with ever increasing rapidity—and finally collide.

Thus there is still another kind of collision that might occur—a stellar encounter. If our sun were to be hit by a passing star, as in the imaginary incident above, the results would undoubtedly be fatal. The energy of impact would generate enough heat to transform all life into a sprinkling of ashes, and finally the dark solid planets into a glowing gas. It may be that the stellar explosions called *novae*, or *new stars*, are such collisions.

In *The Milky Way*, Bok has calculated the chances of the sun being struck by a passing star. He figures that *a star of the size of our sun will collide with a similar star only once in 200,000,000,000,000,000 years*. The rarity of the phenomenon is illustrated by noting that in the Milky Way, estimated by Bok to contain 200,000,000,000 stars, a collision between any two stars will happen once in 1,000,000 years. If the age of our galaxy is taken at its lower limit, or 2,000,000,000 years, it follows that not more than 2,000 collisions have occurred.

In the future, if a star were to approach the solar system, there would be ample warning before any physical effects were felt. Astronomers would detect a very gradual increase in the brightness of the incoming star. But it probably would take at least hundreds of years before a dim star became as bright as Sirius, Vega or Canopus. Each succeeding generation would observe the visitor with greater interest —which finally would surpass the brightest stars in magnitude.

If a collision occurred in the age of space travel, it might be possible to escape to a planet circling another star. It might be possible, for example, through skilled use of atomic energy, to propel the earth on an interstellar voyage. The material of our planet itself would have to be used up for the initial operation of pushing the earth beyond the range of solar gravitation, for subsequent steering, and to provide terrestrials with heat, light, and food during the great voyage. The shortest of such voyages would require hundreds of thousands of years; but if the trip was considered necessary, it might perhaps be undertaken. (By a similar method of locomotion, it might be possible to dispose of the moon before it came dangerously close to the

earth, or to travel to a new planetary system with the death of the sun.)

If a star passed within the distance of Neptune from the sun, the effect probably would be very slight. As seen from the earth, a star on the order of the sun would shine with a light of about 40,000,000 stars of the first magnitude. If Pluto and Neptune were near enough at the time, they might be drawn into the system of the alien object and be carried off by their new luminary. After the visit, the sun and its remaining planets would move in a direction deviating somewhat from its original path.

If a star came within a few million miles of the sun or made a grazing collision, the effects would be different again. There would be tidal upheavals in the stellar objects, and the crests of the waves might break off to form new worlds. Indeed, according to the Planetesimal Hypothesis, the solar-system planets were formed in this manner. Another possibility is that some of the planets might be captured. Imagine what it would be like to live on a "kidnapped" planet! Not only would there be a new sun, but the length of the year and the intensity of the seasons, together with other familiar occurrences, probably would be modified. If no harm came to the earth or its inhabitants, one might take delight in these variations. Certainly astronomers would find them interesting. There is still another possibility. If the sun and the visiting star became inextricably interlaced, they would revolve around a common centre of gravity, like the earth and moon. In such a double-star system, there would be a drastic reorganization of the planets, in which those closer to the new star would revolve around it. As seen from the earth, both suns

would be united in the sky at times; at others one alone would light up the country for a few hours, following which the other one would also rise and illuminate the landscape. So that actually there would be very little real night at all!

Four

THE EXPLOSION OF THE SUN

FOUR

THE EXPLOSION OF THE SUN

"... THE DAY OF THE Lord will come as a thief in the night; in the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burned up."

Thus St. Peter writes in the Second Epistle, and it is a notable fact that all religions have prophesied a flaming end to the kingdom of man. The *Zend-Avesta*, the sacred writings of the ancient Persian religion, and the Koran, the Mohammedan sacred scripture, both present this vision. It has already been shown how a stellar encounter could reduce all life to ashes. According to still another astronomical theory, the prophecy of the destruction of the earth by fire may be fulfilled.

The sun, a typical star, may some day explode, emitting for a time several hundreds of thousands, or even several thousand millions of times, its former heat and light. In half an hour the sunward side of the earth would be burned to a crisp. The night hemisphere, even before the rotation of the earth exposed it to the sun, would be devastated by clouds of live steam from boiled-away oceans ("And when the seas shall boil," reads the Koran with regard to the day of doom). Within a few days the earth would be enveloped and vaporized by enormous clouds of metallic vapours ejected

from the sun. The only remaining trace of the earth would be a little condensation in a rapidly expanding shell of gas.

Such conflagrations in the heavens have been witnessed a number of times in the course of recorded history. Men looking out from the earth have seen, in the remote depths of space, tremendous outbursts of light. These apparitions are called *novae*, or *new stars*. The early astronomers called them new stars because they thought they really were creations in the cosmos. Without telescopes they could not tell that these were dim and distant stars undergoing a remarkable change.

In 134 B.C. the first new star on record appeared. It was seen in the constellation of Scorpius, the Scorpion, and is said to have suggested to Hipparchus, the Greek astronomer, the preparation of the first star catalogue. Hipparchus' Star must have been a truly remarkable object, for it was visible in full daylight.

Old Chinese chronicles show that a bright "guest" star or nova was observed on July 4, 1054, at a position in the sky corresponding with that of the Crab Nebula, a slowly expanding luminous cloud of gas. It is believed that the Crab Nebula is the remnant of the new star of 1054.

The most celebrated appearance of a nova was that of 1572. It is known as "Tycho's Star" because the celebrated Danish astronomer (whose remains, with his gold and silver artificial nose—made necessary by a duel—were disinterred and reburied in 1901) was most assiduous and successful in his studies of it.

"When I left Germany to return to the Danish shores," says Tycho, "I stayed at the ancient and admirably situated residence of Herritzwaldt, belonging to my uncle, Stenon Bille, and I was in the habit of remaining in my chemical

laboratory until nightfall. One evening, when I was contemplating, as usual, the celestial vault, whose aspect was so familiar to me, I saw, with inexpressible astonishment, near the zenith, in Cassiopeia, a radiant star of extraordinary magnitude. Struck with surprise, I could hardly believe my eyes. To convince myself that it was not an illusion, and to obtain the testimony of other persons, I called out the workmen employed in my laboratory and asked them, as well as all passers-by, if they could see, as I did, the star, which had appeared all at once. I learned later on that in Germany carriers and other people had anticipated the astronomers in regard to a great apparition in the sky, which gave occasion to renew the usual railleries against men of science (as with comets whose coming had not been predicted).

"The new star was destitute of a tail; no nebulosity surrounded it; it resembled in every way other stars of the 1st magnitude. Its brightness exceeded that of Sirius, of Lyra, and of Jupiter. It could only be compared with that of Venus when it is at its nearest possible to the earth. Persons gifted with good sight could distinguish this star in daylight, even at noonday, when the sky was clear. At night, with a cloudy sky, when other stars were veiled, the new star often remained visible through tolerably thick clouds. The distances of this star from the other stars of Cassiopeia, which I measured the following year with the greatest care, has convinced me of its complete immobility. From the month of December, 1572, its brightness began to diminish; it was then equal to Jupiter. In January, 1573, it became less brilliant than Jupiter; in February and March, equal to stars of the 1st order; in April and May, of the brightness of stars of the 2nd order. The passage from the 5th to the

6th magnitude took place between December, 1573, and February, 1574. The following month the new star disappeared without leaving a trace visible to the naked eye, having shone for seventeen months."

Tycho's Star appeared on November 11, 1572, a few months after the Massacre of St. Bartholomew. General uneasiness, popular superstition, and the dread of the end of the world (long since announced), were an excellent *mise en scène* for such an apparition. Astrologers soon proclaimed that it was the Star of Bethlehem, whose reappearance foretold the return of Christ, the Last Judgment and the Resurrection. But the star went out without having produced any other disaster than that which human folly itself creates.

Just as the appearance of a new star had led Hipparchus to prepare his famous star catalogue, so the appearance of the star in Cassiopeia revived Tycho's interest in observational astronomy and led him to carry out his great programme of exact observation, which was subsequently to supply the foundations for mathematical astronomy.

In 1604, a new star made its appearance in the constellation of Ophiuchus, the Serpent Bearer. It is often called "Kepler's Star" because of the attention paid it by the great German astronomer who gave us the laws of planetary motion. Kepler tells us that it did not have the appearance of a comet; moreover, that it kept its place unchanged, showing without a doubt that it belonged to the star depths, not to nearer regions. At maximum Kepler's Star rivalled Jupiter in brightness. In fact, it seemed very closely to have resembled Tycho's Star, not only in appearance and in the degree of its brightness, but also in the duration of its visibility, which was eighteen months.

At the beginning of the twentieth century, a celestial spectacle, such as had not been seen since the time of Tycho and Kepler, surprised the world. On February 22, 1901, an amateur astronomer, the Rev. Dr. Anderson of Edinburgh, Scotland, observed a strange object in the constellation of Perseus, the Prince. He recognized its true nature at once and immediately telegraphed the news, which awoke the startled attention of astronomers all over the world. When first seen, the star was less than the 2nd magnitude; but within twenty-four hours it was ablaze, surpassing stars of the 1st magnitude.

On the night before its coming, nothing was visible at the spot in the sky where the new star appeared. On February 21 a photograph had been made of that very region, and this photograph revealed everything down to the 12th magnitude. To one who knew the stars, the appearance of the intruder in a well-known constellation had the effect of a sudden invasion. Capella, one of the brightest stars and the unchallenged ruler of that part of the sky, was abased by the lustre of this object of alien aspect, whose arrival seemed to portend the beginning of war in heaven.

Unlike the historical novae, Nova Persei remained at its brightest for only several days. After a few months the naked eye could no longer perceive it, although it was picked up with the telescope. When the star had fallen to 9th magnitude, another extraordinary change occurred: a nebulous cloud appeared around the stellar nucleus and spread wider and wider, like a wave expanding around a centre of disturbance. At length the cloud disappeared, leaving only a faint nebulous star behind. The catastrophe was over.

Astronomers have divided these stellar explosions into

two classes, novae and supernovae. Novae blast into an intensity several hundreds of thousands of times the normal luminosity of the sun, while supernovae may attain a maximum brightness of ten to a hundred million suns. The "guest" star of 1054, Tycho's Star, and Kepler's Star probably fall into the class of the supernovae. If, as has been suggested, the Star of Bethlehem represented one of these cosmic catastrophes, from the information about it, one may deduce that it also was a super-explosion.

Kepler's Star was apparently the last supernova within the Milky Way. But there is reason to believe that the uniformity of the heavens will soon be interrupted by another great phenomenon. From historical data, modern astronomers estimate that the average frequency of appearance of supernovae in the Milky Way is about once in every 300 years. Almost three and a half centuries have elapsed since the last apparition.

The physical processes that cause a faint telescopic star, after shining with a steady light for a thousand million years, to flash out within a few days as bright as Jupiter or Venus, must be extraordinary. It must be confessed, however, that the cause of the sudden release of such a vast store of energy is mysterious. The conditions that might possibly be responsible for these catastrophic events can only be speculated upon.

Like the pictures in a kaleidoscope, the ideas in science are continually changing. A scientific theory is merely a picture living in the compartments of the mind, a picture which must be discarded when it no longer fits the observed facts. By discarding old ideas which no longer conform with observation and experimentation, and inventing new ones, the scientist is brought ever closer to the truth.

No wonder the old and new theories of new stars are so numerous and so different from each other. One of the early theories accounted for these objects by supposing them to be endowed with very rapid movements. Arago, however, showed that to pass from the 1st to the 2nd magnitude by a simple change of distance, a star, travelling with the speed of light, would require about six years. This assumed speed is thousands of times greater than the velocity of the stars; moreover, it is much too slow to explain the phenomenon of the nova. Tycho's Star, for example, underwent the change in magnitude in a month.

Another theory explained the variations in brightness by movements of rotation. According to this idea, the various faces of the star were supposed to be of a prodigiously unequal brightness.

Still another theory attributed these appearances and disappearances to the movement of dark nebulous masses between the star and the solar system. When the cosmical clouds had entirely passed, the eclipse was supposed to end.

These are the theories of yesterday now discarded. Another old theory, that of a grazing collision or near approach of two stars, is still entertained today. Here the energy of motion of the colliding bodies is transformed into heat and light. The theory explains the observed sequence of phenomena and affords a sufficient supply of energy. However, because of the extremely sparse population of stars in space, the chances of collision are negligibly small. According to one calculation, in the past 2,000,000,000 years, not more than two or three such collisions could have occurred in the Milky Way. Even if Bart J. Bok's calculation (that over 2,000 star collisions have occurred) is

accepted as being more nearly correct, this theory cannot account for the number of observed novae.

It would appear that the existence of dead stars in the universe would greatly raise the chances of collision. There are astronomers who believe that there are multitudes of these dark, cold globes, in addition to the shining myriads which dot the heavens. The violent precipitation of one of these bodies upon the surface of a blazing star would be fabulous indeed: like the legendary phoenix, the dead star would rise from the "flames" reborn, its mass exploding into gases. Perhaps even these gases would one day be used in the formation of a new star.

Some astronomers regard novae as due to the rush of a star into some resisting medium. Clouds of dust and gas, called *galactic nebulae*, are known to spread their gauzy nets throughout all creation. Some of these clouds, the dark nebulae, are of inky blackness and cut off our view of the more distant stars in the Milky Way. Others shine by the light of neighbouring stars and appear as giant luminous nebulosities. The nebulae are of huge dimensions and take on various chance forms and shapes, depending upon the whims of Nature. Thus the beautiful Filamentary Nebula in the constellation of Cygnus, the Swan, extends across space for a distance of about 40,000,000 times the distance between the earth and the sun.

If a star should plunge into a field of nebulous material, it would burst into high luminosity, just as a meteor is illuminated by entering the earth's atmosphere. This hypothesis meets with several difficulties, however. While it can account for enough energy to create ordinary novae, it fails to provide the enormous energy liberation in supernovae. Moreover, because nebulae vary so much in their

densities and geometrical dimensions, it is difficult to see how they could explain the remarkable similarity of all observed nova explosions.

One of the most acceptable, though still unaccountable, theories of novae is explosion within a star, owing to a sudden release of sub-atomic energy. The sun and stars shine by a gradual release of the stored energy of atoms. Release of this energy on the earth has been accomplished on a relatively small scale: the atomic bomb, which hung momentarily over Hiroshima, was in the nature of a pygmy sun, shining grotesquely by nuclear fission. It has been suggested that some special thermonuclear reaction comes into play when the central temperature of the evolving star reaches a certain critical value, releasing heat with explosive violence.

This theory implies that the conditions which operate to release the energy of a star with such great regularity may at times lose this control, only regaining it after a cataclysmic readjustment. It also implies that it is a natural stage, instead of a chance happening, through which every star must pass. Certainly the successive shells of surface material which seemed to be blown off new stars suggest that some kind of an explosion has occurred.

The chances of the sun's becoming a nova once during its life period are quite high. At least twenty stars of the Milky Way explode each year. George Gamow, a professor of physics at George Washington University, estimating the age of our universe at about 2,000,000,000 years, concludes that some 40,000,000,000 stars have already exploded, unless more stars than usual are exploding at the present time. Since the Milky Way contains about 40,000,000,000 stars, it would seem that practically every star must explode at

least once during its evolutionary history. The chance of the sun's becoming a nova within the next few years, however, is only about one in several thousand millions, according to Gamow's reasoning. Moreover, it is likely that each star can explode just once during its lifetime, and it is possible that the sun underwent this metamorphosis in the distant past.

Assuming, with many modern astronomers, that most of the stars are surrounded by planets, it seems obvious that novae have already caused the end of myriads of worlds. The destruction wrought by the fall of the first atomic bomb over a populated area fills every man with horror. But this explosion would be like that of a tiny firecracker in comparison to the sun becoming a nova. It seems unlikely that our sun will become a supernova. Such an explosion is very rare and seems to take place only in the case of stars larger and heavier than the sun. If the sun explodes, therefore, our end will probably be announced throughout the universe by a nova of the ordinary kind.

On the fatal day, when the trumpet of the world's dissolution is sounded, the lives of the two thousand million inhabitants of the earth, and of the possible inhabitants of the other planets in the solar system as well, will be reaped.

The loss of one life or ten is easily grasped, so is the destruction of the life of a large city. But the death of the inhabitants of the whole world, not to mention that of the possible life on other planets, is vast beyond all human comprehension. However, an understanding of this concept is not necessary, as there will be no one left in the solar system to grasp it.

Because light does not pass from one point to another instantaneously, but by degrees, and because it takes light about eight minutes to cross the 93,003,000 miles separating

the sun from the world, the explosion will not be felt until about eight minutes after it has occurred. "The heavens shall pass away with a great noise," but because of the absence of air (which is the medium of sound) between the sun and the earth, the noise of the catastrophe will not be transmitted to us.

On the side of the earth turned to the heretofore cheerful sunshine, life, which has been evolving to higher forms for the past 1,000,000,000 years, will be cut down by the tall mower of death so swiftly that no one will have time to realize what has happened. "The day of the Lord will come as a thief in the night."

The sun seething with unconscionable fury overhead, hot air rising from the continents and oceans and cold air rushing in at hurricane strength to replace it, the sky filled with weird patterns of celestial fire and the booming voice of the thunder, the sea boiling and filling the atmosphere with hot showers, the projected picture of the day of wrath is fearful beyond words.

The fate of the dwellers on the night side of our planet will probably differ from the rest of mankind. Before they are turned, by the rotating earth, into view of the destroying sun, they will be stifled by hot air brought by gargantuan convection currents from the other side of the world and scalded by steam from boiled-away oceans. The sun will afterwards reduce their corpses to ashes.

Several days after the beginning of the cataclysm, the shells of gas blown off the sun will engulf the earth in a frightful holocaust. The earth, together with the other planets of the solar system, will be transformed into a tenuous gas and poured back into the night of space, which generated all the worlds and once brought forth from its

womb the earth. "And the elements shall melt with fervent heat, the earth also and the works that are therein shall be burned up."

On some remote world, circling another star, astronomers will no doubt register the appearance of the nova in their annals of science.

Five

THE DEATH OF THE SUN

FIVE

THE DEATH OF THE SUN

IN THE PRECEDING chapter it was shown how the world might end in fire and how this is entirely in accord with the prophecy of St. Peter. Another theory is that the sun is becoming hotter and hotter and threatens to burn up everything on the earth in several billion years, after which it will begin to die, growing colder and dimmer every moment until the earth is transformed into a veritable cemetery of ice. Modern science shows, then, that there are several ways by which the earth or its life might perish. The account of the last days of the world in the gospel according to St. Mark corresponds well with the circumstances attending the death of the sun. "But in those days, after that tribulation," reads the Scripture, "the sun shall be darkened, and the moon shall not give her light."

The description of the sun as the heart of the solar system is an appropriate one. The sun is the central object of this system, a huge globe of incandescent gases that supplies essentially all of the energy to the planets. The importance of the sun is seldom appreciated by man: the sun's regularity precludes his taking very much notice of it. It is only when an organ ceases to function properly that its existence forces itself upon us. This would be true also of the sun.

Imagine, then, what the world would be like if the sun were suddenly to stop functioning. The earth would be plunged into the deepest night, lit dimly by the stars.

The moon and the planets, which shine by reflected sunlight, would be extinguished. Within a week, the tropics, having given up their oppressive heat, would be hemmed in by snow. Winds would stop blowing. Rivers would cease to flow. And the great oceans would freeze to their very depths.

With the aid of coal, oil and wood, here and there man might be able to postpone his fate for a short time. But he could not long endure the invading cold, and all living things would soon be wound up in an immense white shroud. In all probability, the inhabitants of the earth would be left as they were when the breath of life departed and the Death Angel, with his instruments of frost and snow, stiffened and embalmed them for eternity. The natural world would be seen at its most haunting, unlit except by stars, the frozen dead observed with just enough light to make them solemnly and distinctly visible. Eventually, as the temperature sank to a few degrees above the absolute zero of interstellar space, the atmosphere would liquefy and freeze upon the lifeless world—a frightful demonstration of the importance of the sun.

Today it is recognized that there is hardly a phenomenon on the earth the origin of which cannot be traced back to the energy radiated by the central luminary. In particular, the sun is the source of practically all the energy on the earth. Water power is a converted form of solar heat. The sun evaporates the water from ocean and sea surfaces and deposits it on higher levels from which it runs back to its original reservoirs. Wind power is produced by the sun, which unequally heats the earth's surface, with a consequent motion of air. The energy in coal, oil, and wood originally came from the sun. Under the influence of light,

sugars and starches are produced from carbon dioxide and water in green plants, whose protoplasm contains the remarkable green pigment, chlorophyll. This pigment enables the living material to use sunlight as the source of energy for the synthesis of carbohydrates. When a tree is burned, the energy that its growing leaves had received and stored up from the solar rays is released.

Photosynthesis in chlorophyll-bearing plants is a highly important activity. *It is the basis of the food supply of the whole living world.* Almost without exception, these plants are the only forms capable of making their own energy-yielding foods. Hence, all other living things, which require organic nutrients, are dependent upon them.

The glow from a piece of coal is fossil sunlight. Some 200,000,000 or 300,000,000 years ago, when the sea lilies reached the peak of their development; when the only air-dwelling creatures were the insects; when great armies of giant dragonflies and cockroaches existed, and the progress of organic life had not advanced beyond the creation of some uncouth reptiles or strangely formed fishes, the leaves of vast tropical forests imprisoned solar energy. In the great dismal woods of the Carboniferous Period, ferns, mosses and other plants accumulated in swampy soils which are not favourable to the bacteria causing decay. As ages passed, they were covered by accumulations of dust and rock, which pressed the decayed vegetation into solid layers. Water and compounds of sulphur, nitrogen and hydrogen were forced out by the tremendous pressure of the weight above until finally carbon, in the form of coal, remained.

The accumulation of primeval vegetable and animal matter in bogs suffered a similar fate to form the oil deposits in the subterranean world.

It is, then, the sun which murmurs in the brook, which whispers in the wind, which moans in the wave, which blossoms in the rose, which whistles in the throat of the nightingale, which gleams in the lightning, which rolls in the thunder, which sings or wails in the great symphony of Nature. Without the sun's rays, the surface of our globe would be dead and motionless. Since it is inconceivable that the sun should be a perpetual-motion machine, a catastrophe of cold seems to be inescapable—some day.

At the present time, every square yard of the earth's surface receives an average of 1½ horse-power of energy. Considering the supply of sunshine as a public utility, at the rate of 1½ cents per kilowatt hour (which is the price of current where large amounts of power are consumed), the cost of sunshine for the city of New York would be $200,000,000 for one twelve-hour day. The cost of sunshine for a similar period for the entire earth would be more than $100,000,000,000,000. If the Federal Government were to have to pay for sunlight for the United States alone, in would call for an annual budget of $686,000,000,000,000.

Of course, this gives an idea only of that part of the sun's energy received by the earth. The sun is radiating energy in all directions into space, and the earth intercepts only 1/2,000,000,000 of this energy. The total amount of energy received by the earth must be multiplied two thousand million times in order to arrive at the total output from the sun. The total output is found to be 343,000,000,000,000,000,000,000 kilowatts; and at the rate of 1½ cents per kilowatt hour, it would cost $200,000,000,000,000,000,000,000 to keep the sun lit in the solar system for one twelve-hour period.

All speculations on the future of the physical universe

depend upon the answer to one question: what is the origin of the heat and light of the sun and stars?

According to mythology, when Zeus withheld fire from man, Prometheus stole it from heaven and brought it to the earth again. The story is that Zeus prevented the hardwood firesticks from being effective when rubbed against the soft ones. Prometheus, therefore, stole fire by holding a rod close to the sun. Enough fire was taken to make the pith of a stalk of giant fennel smoulder.

That the sun burns like coal or wood is the oldest idea as to the origin of solar heat. Prometheus undoubtedly considered that the "fire" of the sun was exactly the same as that which is made when two sticks are rubbed together. He would have been astonished to learn, however, that *the sun is too hot to burn.* The surface temperature is 11,000° F., while it is estimated that the interior temperature is 40,000,000°. In combustion, oxygen combines with another substance, producing heat and light; but the solar temperatures are far too high to allow oxygen to combine with any other element. Under too-high temperatures, complex chemical substances are broken down into elements; carbon dioxide is broken down into carbon and oxygen, for example, and it is believed that the gases forming the sun must consist of a mechanical mixture of pure elementary substances.

Moreover, if the sun's heat and light were produced by ordinary burning, and if the sun were composed of the purest coal, it could not have kept up its present rate of radiation for more than 1,500 years. Thus, if the sun had been set afire about the time that the Angles and Saxons invaded Britain, it would by now have completely burned to ashes.

Recognizing the limitation of chemical heat, astronomers long ago looked for other explanations for the maintenance of the sun's energy. Some suggested that an enormous amount of heat and light would be generated by a steady hail of meteors upon the sun's surface. The amount of meteors that could collide with the sun was calculated, however, and found to be inadequate as a source of fuel. Astronomers, therefore, concluded that the sun's supply of energy must come from within itself.

In 1854, Hermann von Helmholtz, the famous German physicist, presented his contraction hypothesis, which most astronomers accepted with or without reserve, up until and through the early years of the twentieth century. According to Helmholtz, the sun was originally a giant sphere of cool gas with a diameter which extended beyond the orbit of Neptune. Under the pull of its own gravity, the outer parts of the primitive sun fell toward the centre; and the effect of contraction was to produce heat, just as the compression of a gas by a moving piston in a cylinder causes a rise in the gas's temperature. Calculations show, however, that by contracting from almost infinite dimensions to its present size, the sun could shine for no longer than 50,000,000 years. This is too short a period from the point of view of the geological time scale: the tropical forests of the Carboniferous period were storing up solar energy 200,000,000 or 300,000,000 years ago.

The only remaining theory to account for the energy of the sun seemed to be that matter was being converted into energy. This idea is older than Albert Einstein or the atomic bomb. Sir Isaac Newton (1642-1727) once speculated upon the possibility of changing "bodies into light or light into bodies."

In 1905, a young man named Albert Einstein, who was then only twenty-three years old, published a short paper in which he supplied the quantitative key to the conversion of matter into energy. His formula, $E=mc^2$, where E is the energy in ergs, m the mass in grams and c the velocity of light (that is, 3×10^{10} cm. per second), is now famous. The equation has been put to a successful test with bodies whose energy content is variable to a high degree, for example, with radium salts. Here, indeed, is an abundant source of power. If half a thimbleful of water were completely transformed into energy, it would furnish the heat produced by burning 20,000 tons of coal. In order to keep the sun shining at its present rate, 4,200,000 tons of material would have to be converted into energy each second. The sun is so massive, however, that its mass would be thereby reduced by only a tenth of 1 per cent. in 15,000,000,000 years.

It is believed that in the sun lighter elements are assembled into heavier components with the release of energy. The process is thought to be the conversion of hydrogen into helium, in which four atoms of hydrogen are packed together to form one atom of helium. Since the atomic weight of hydrogen is 1·00813 and that of helium 4·00386, 0·2866 units of the original mass would appear as energy. The reaction is produced by high temperatures and aided by the catalytic action of carbon and nitrogen.

The complex nuclear reactions by which hydrogen might be transformed into helium within the sun are known as the *carbon cycle*, and were first worked out by Dr. Hans Bethe, a Cornell University physicist. (In 1941, the carbon cycle was subjected successfully to a rigorous theoretical test.) Dr. Bethe first learned about the importance of nuclear reactions for the production of solar energy at the Washington

Conference on Theoretical Physics of 1938. Returning home by train from the conference, he figured out the nuclear reactions before the dining-car steward announced the first call for dinner.

Although Prometheus did not know of the true nature of the "flame" he stole from heaven, today mere mortals have discovered the ancient riddle concerning the sources of solar radiation; moreover, they have released the energy by which the stars shine upon the earth. And the last time that Prometheus descended from the sky, this great benefactor, who taught mankind all the useful arts, was solidified in a golden statue above the skating rink in Radio City, New York.

In the way of digression and of the wildest fantasy, the possible inhabitants who dwell in the sun might be imagined. Life on the earth is based upon chemical action, and it might be that solarians are based upon the energy released by subatomic processes. Upon the sun's seething surface or deep within the solar interior, flamelike organisms might exist, perhaps even excelling man in intelligence. Terrestrials will probably never know if such incandescent beings have been created, for it appears quite impossible that man will ever visit the City of the Sun. To make such a journey would be to suffer the fate of Icarus, who approached the sun too closely, so that the wax that fastened his wings melted and he drowned in the Aegean Sea.

According to the physicist George Gamow, *the consumption of the sun's hydrogen "fuel" is making the sun grow hotter and brighter, instead of colder and dimmer, every moment.* Under solar conditions, helium is less transparent than hydrogen; and as more and more of it is formed in the solar interior, Gamow believes that the energy produced in the sun will

undergo greater difficulty in journeying towards the surface. The accumulation of energy in the sun's centre will lead to a corresponding rise in temperature, which will increase the rate of energy production, for the rate of thermonuclear transformations occurring in the sun depends not only upon the amount of hydrogen present, but also upon the temperature causing the reaction. A decrease in the amount of "fuel," then, will cause an increase in the temperature, which will result in the last pieces giving much more heat and light than when the "furnace" was full.

Gamow's calculations indicate that the solar radiation must increase a hundred times as much as it is at present by the time the amount of hydrogen is about to fall to zero, and that, with its decreasing hydrogen content, the sun must first grow a little larger and then slowly begin to diminish in size. This new development is revolutionary. Classical theory maintained that the inhabitants of the earth would be destroyed by ice with the death of the sun. Instead, it would appear that life is doomed to burning because of the intense heat which will be generated by the sun toward the end of its normal evolution. In those days, the oceans and seas will boil, but the temperature will probably not be high enough to melt the rocks forming the earth's crust.

Under such conditions, there would be three possibilities for survival. Man might explore the mysterious world beneath his feet, burrowing like a mole, constructing vast, air-conditioned underground cities for humanity. In this strange, new world, there would never be the elevating influence of a starry sky; and it is curious to speculate upon the effect that this might have upon the state of civilization. If, for example, clouds perpetually covered the earth, but

if they were not so thick as to prevent the sun's energy from penetrating the soil and growing the crops, we would be creatures of exceedingly narrow limits. The human race would go about its lowly task of growing corn for food and cotton for dress, knowing nothing of the greatness of the universe—and of man himself.

A second possibility would be to escape the earth and colonize another world; Neptune, for instance, might become a haven for terrestrials.

A point of importance is that the rise in temperature will be slow, requiring about 10,000,000,000 years before the highest stage of luminosity is reached, after which the sun will commence to die. The slow rise in temperature in all likelihood will be accompanied by evolutionary changes in the biological world, so that terrestrial life will become more adapted to the greater heat. Perhaps man will survive by developing a horny, semi-heat-resisting covering. Such animals with exoskeletal structures actually exist; take, for example, the lobster. The covering might be impregnated with or made out of some heat-resisting element, like asbestos. If the chemical compounds of which living matter on the earth is composed do not alter to meet the changing conditions, however, it would appear that the biological species will degenerate; and man will have vanished from the earth long before the temperature becomes really intolerable. Only the simplest and most stable of micro-organisms will be here to witness the final radiation efforts of the ancient sun.

When the sun has completely burned up its fuel and come to the end of its hydrogen evolution, Gamow believes that it will continue to shine for a time by the process of contraction. Shrinking rapidly in size, its luminosity diminish-

ing at a swift rate, the sun will retreat to its present energy output in about 5,000,000 years. Finally the sun will turn into a giant lump of dead matter enveloped in eternal ice and surrounded by a system of frozen planets.

One tends to imagine the dead sun as a giant stone, similar to the earth, only larger, rolling through space. But the present knowledge of the properties of matter indicate that the interior of the sun will be vastly dissimilar to the interior of the earth. Because the sun is so massive, it will produce, in its central regions, pressures surpassing a certain critical atom-crushing value; and the structural parts of atoms, which prevent them from being squeezed into one another under normal pressure, will be disrupted. Electrons of one atom will then penetrate into the interior of another, and matter in the sun's interior will exist in a peculiar new state: *it will behave like an ordinary gas and it will look like some molten heavy metal.*

Thus the sun is destined to a complete internal collapse. It is estimated that it will have a diameter smaller than that of Jupiter and comparable with that of the earth, and that the density of the sun will rapidly increase toward the centre. The average density will be 3,000,000 times greater than the density of water; and each cubic centimetre of the material in the central regions of the sun will weigh about 30 tons.

Among the stars above us, there is observational evidence for the existence of collapsed stellar bodies. Of course, dead stars cannot be seen. But stars which have already exhausted their hydrogen "fuel" and are living on the gravitational energy generated by their slow contraction are to be found. Such a star is the companion of Sirius, the Dog Star. It is estimated that the radius of this star is fifty

times smaller than the sun and that its average density is 200,000 times the density of water.

It may be that our speculations on the future of the sun are little more than scientific daydreams. But one thing is certain concerning stellar evolution: the death of the sun and stars is inevitable; wound-up watches and wound-up suns must run down some time.

Going upon the assumption that life still will be in existence when the sun begins to die (that is, if the sun does not become hotter and hotter before giving up its light or if life survives the increasing heat by adaptation, by building underground, or by escaping to and returning from other worlds than ours), an interesting picture of the human reactions towards the death of the sun can be projected.

The Arctic and Antarctic Oceans will freeze first, and this will result in a general secondary lowering of temperature and an extensive glaciation. The North and South Atlantic and Pacific Oceans will gradually be frozen, leaving only the ocean near the Equator in a liquid state. But slowly and surely more and more floating ice will be found in tropical regions, until all the waters of the earth are hardened into ice.

When the continents reach the freezing points, streams will cease to exist; and the rain and snow falling on them will become ice, which cannot run off as water does. Hence thick, slowly moving icecaps will be formed, like the one that cloaks the Antarctic continent today.

Life as we know it could not endure under such conditions. It might survive by building elaborate underground shelters of the order of Admiral Byrd's Little America. Another possibility would be to move closer to the hearth of the solar system, just as one draws closer to a

fire when it begins to die. The whole population of the earth might be transported to Venus or Mercury; but with the death of the sun, it would have to set out for another planetary system. If modern theories of creation are correct, the main body of stars was formed at the same time; and when the sun is dying, the entire universe will be filled with dead or dying stars. It is believed, however, that the process of star formation is still in progress, so that there may be some live stars with planets to colonize when our great cosmic catastrophe takes place.

Still another possibility would be to construct our own sun, a source of heat and light which might be suspended in the sky and hold the hovering demons of cold and darkness at bay. This artificial sun would operate by subatomic energy. In the remaining years of grace, man might learn how to run the carbon cycle. Hydrogen, the fuel, is abundant, and other light atoms, such as lithium, are also plentiful sources of energy. With several thousand millions of years of time at his disposal for research, man should be able to develop cheap, abundant and manageable subatomic power.

The marvellous power of adaptation, which physiology and palæontology have revealed in every variety of animal and vegetable life, will undoubtedly make terrestrial life more and more adjusted to the increasing cold, just as it did during the Pleistocene Ice Age, when there was a general, worldwide lowering of temperature. Perhaps the stability in temperature of that future time may make it seem doubtful whether any really intelligent race could have existed in a period subjected, as is ours, to such variations in temperature. In *Sketch for a Self-Portrait*, Bernard Berenson suggests just such an idea. Speaking of climate

and the United States, he voices the presentiment that the United States may, in the long run, prove unfit for man's habitation. Since the mountains extend from north to south, instead of from east to west as in parts of Europe, the land is open to the extremes of heat coming from the steam-bath of the Caribbean and to the icy blasts from the Arctic Ocean. Berenson points out that the changes are sudden and violent, the thermometer rising or falling as much as 60° F. in the course of a waking day. If a glass is plunged first into hot water and then immediately into cold, it will crack; and Berenson makes the observation that our veins and arteries are more sensitive than any glass and that if they do not crack they wear and tear.

If interplanetary travel, artificial suns, and underground cities prove to be unfeasible, and if the adaptation of life does not keep pace with the increasing cold, the biological species will most likely begin to degenerate. As the sun grows cold, the quantity of rainfall will diminish by reason of the lesser amount of evaporation of sea water. Vegetation will entirely change its aspect, increasing the volume of its leaves and the length of its roots, seeking in every way the humidity necessary for life. Species which are not able to adjust themselves to the new conditions will vanish; the rest will be transformed. Not a tree or plant with which we are familiar will be seen. There will be no ashes, no oaks, no elms or willows; and the landscape will bear no resemblance to that of today.

Life and human activity will imperceptibly retire toward the zone between the Tropic of Cancer and the Tropic of Capricorn. During many centuries equatorial mankind will attempt dramatic expeditions to find once more, under the ice, the sites of Leningrad, Berlin, London, Paris, New

York, Constantinople and Rome. As the habitable surface of the earth becomes more restricted, the world's population will diminish, men falling like poppies before the coming of winter. Finally, only a few million inhabitants will remain, scattered in groups along the Equator, where they will wage the last combat with death. A suppositious traveller of the twentieth century in those times might discover, in the equatorial zone, immense cities of glass, resembling giant solaria.

Perhaps civilization will add a few million years to its life by the direct utilization of solar heat, that is, for example, by collecting the last enfeebled rays of the pale sun with huge concave mirrors. This method is already employed to run the refrigerators of the cold-drink stands in the Arizona desert and to heat water for the public baths of the Oriental city of Tashkent.

Without doubt, the lamps of the theatre will have been extinguished and the actors will have departed long before the heat and light of the sun have failed. It is at this time, not when the sun will have become a dark ball with the earth floating as a charnel ship round it, that the end of the world must be reckoned.

The end! The hour will strike upon the timepiece of destiny as the finger-tips of Death touch those of the sole survivor of humanity. And the races of mortal creatures, which were let down into the fields from heaven by a golden cord, or generated from the sea or the rock-beating surf, or were borne to the earth as a germ on a falling star, will be no more. The equatorial city of glass will be dark, putting into the shine of star lights a wall of black windows. New York, London, or Paris in the early morning hours, when millions upon millions are sleeping, is in the nature of

a preview of this city when the earth becomes cold in the sleep of death. The general loss of consciousness in a large community before the sunrise generates an impression of abandonment, as if it were the fall of the city, the end of time.

Towards the end of the sun's life, the day-star will appear like a luminous drop of blood against the black velvet of the sky. Finally, the sun will become a dark globe and be swallowed up into the night. The moon and planets, which shine by the reflected light of the sun, will also be extinguished, and the earth will receive no other light than that of the remaining stars.

The solar heat having vanished, the atmosphere will liquefy and freeze upon the lifeless globe, and an absolute calm will reign forever. No clouds will form; no snow will fall; neither will there be any breath of air. According to Gamow, the universe will then be populated by dead or dying stars, so that similar conditions will exist on worlds surrounding these stars. Furthermore, the left-over stars will have changed their places in the firmament. The constellations will be deformed, and the heavens will have become unrecognizable.

The astronomer Camille Flammarion speculated about life on dying stars. He imagined the sun—then a dark star, but still warm and electrical, and enveloped in a sort of phosphorescent atmosphere—inhabited by strange creatures, by a marvellous flora, by an unknown fauna, by beings differing absolutely from those who had succeeded each other upon the worlds of its system.

The Antarctic regions have been described as a preview of the earth æons hence when the sun grows cold, the conquering ice smothers life, and the terrestrial globe becomes

a huge white tomb hurtling through eternity. There, at the bottom of the world, the feeling is that of walking in a dead city of another planet; everywhere there is absolute silence, the cumulative silence of a million years.

As in the case of the Antarctic continent, the broad picture of the earth will be that of a lofty desert of ice, out of which, here and there, high black or light-coloured mountain peaks will rise. The vastness, the clearness, the whiteness, the silence and the purity of the whole world will transform our planet into a sermon in ice. But there will also be malevolence in the nature of the physical world; our planet will be as cruel and sinister as its beauty is harmonious.

According to the traditions of the cemetery, if the spirits of the dead rise from their funeral chambers every now and then, imagination may conjure up for us the fearful dances they will perform across the stately fields of ice. It may be that these dances, symbolizing the power of death, will be accompanied by ghostly prehistoric choruses, destroying the black silence of eternal night.

The end of the world may occur in many ways, by the explosion of the sun or by the collision of the earth with the moon or the sun with a star. But the slow death of the sun and cooling of the earth is inevitable and will probably occur before any one of these other astronomical tragedies befalls our world.

This is the way the world ends
This is the way the world ends
This is the way the world ends
Not with a bang but a whimper.

Six

ATOMIC WAR

SIX

ATOMIC WAR

IN *The Sanity of Art*, Bernard Shaw writes: ". . . as these alarms always had their public, like prophecies of the end of the world, there is nothing surprising in the fact that a book which might have been produced by playing the resurrection man in the old newspaper rooms of our public libraries, and collecting all the exploded bogy criticisms of the last half-century into a huge volume, should have a considerable success."

There is one last means of the end that cannot be neglected or the author stands the risk of falling into the trap of playing the "resurrection man." This means is the wartime use of atomic energy.

Albert Einstein and Harold C. Urey, probably more than any other two scientists, have attempted to carry the message of the bomb's power to the people. Both of these men possess a deep sense of social responsibility. This responsibility, not only towards the group of persons existing at the present time, but towards future generations, must be shared by all of us.

In August, 1945, the terrible energy of the atom's nucleus was released on the Japanese city of Hiroshima. Three months later, in an article in the *Atlantic Monthly*, the noted physicist Albert Einstein, whose formula $E=mc^2$ led to the belief that atomic energy could be unlocked, made the following statement:

"I do not believe that civilization will be wiped out in a war fought with the atomic bomb. Perhaps two-thirds of the people of the earth might be killed, but enough men capable of thinking, and enough books would be left to start again, and civilization could be restored."

However, in the *Atlantic Monthly* of November, 1947, Einstein reported: ". . . enough has been said by those who [work in the field of the atomic bomb] to indicate that the bomb has been made more effective." In speaking of the growing scope of atomic war, he said ". . . that unless another war is prevented it is likely to bring destruction on a scale never before held possible and even now hardly conceived, and that little civilization would survive it."

Three years later, in February, 1950, Einstein delivered a memorable speech at Princeton, New Jersey, for broadcast on an N.B.C. television programme. Speaking on "Peace in the Atomic Era," Einstein said: "The armament race between the U.S.A. and the U.S.S.R., originally supposed to be a preventive measure, assumes hysterical character. On both sides, the means to mass destruction are perfected with feverish haste—behind the respective walls of secrecy. The H-bomb appears on the public horizon as a probably attainable goal. Its accelerated development has been solemnly proclaimed by the President.

"If successful, radioactive poisoning of the atmosphere and hence annihilation of any life on earth has been brought within the range of technical possibilities. The ghostlike character of this development lies in its apparently compulsory trend. Every step appears as the unavoidable consequence of the preceding one. In the end, there beckons more and more clearly general annihilation."

Thus, the atomic bomb has been made increasingly

more terrible, while nothing has been done effectively, since the completion of the first atomic bomb, to make the world safer from war. A chronological study of the writings and speeches of Albert Einstein on atomic war reveals the growth of the idea of the end of the world as produced by man. Today this man-made possibility of the end is established on a firm foundation. This is The Year Atom Bomb Eight. It is a question as to whether we shall be alive in A.B. 9 or A.B. 10.

That the fate of humanity depends upon the ability of men to co-operate in avoiding common dangers has been declared not by Albert Einstein alone, but by most of the world's most eminent physicists; by Harold C. Urey, who worked on the atomic bomb from 1940 on, specializing in isotopes of uranium and the production of heavy water; by the Austrian physicist, Lise Meitner, who pioneered in breaking down uranium 235—a feat which led directly to the creation of the atomic bomb and atomic energy; by Niels Bohr, leading Danish scientist who worked on the American development of the atomic bomb; and by J. Robert Oppenheimer, who headed the Los Alamos group of scientists who developed the atomic bomb. All these scientists, who helped to produce the atomic bomb and who presumably know something about it, have given notice repeatedly that civilization is in dire and immediate danger. In spite of these warnings, the peoples of the earth are drifting nearer and nearer to the edge of the abyss—the atomic war. Nations are rearming on a large scale and history teaches that the result of such rearmament is war. At the same time, the psychological forces behind the rearmament policy are growing stronger and stronger—fear, hatred and the pursuit of power and wealth.

The energy liberated by a "nominal atomic bomb" is approximately equivalent to that released in the explosion of 20,000 tons of T.N.T. Expressed in electrical energy, it is roughly equal to the daily output of Hoover Dam, or enough to keep a 100-watt bulb burning for 263,000 years. Yet this gigantic force can be unleashed in the complete splitting of only 2·2 pounds of uranium 235 in less than a millionth of a second!

When an atomic bomb is exploded in the atmosphere, its radiation is absorbed considerably by the air immediately surrounding the bomb, with the result that the air is made white with heat. About one-ten-thousandth of a second after the burst this ball of fire has a diameter of about 90 feet; and the temperature is then 300,000° C.—or fifty times greater than that of the sun's surface. To an observer five miles away, its brightness is 100 times that of the sun as seen from the earth. The fireball attains its maximum diameter of 900 feet after the lapse of one second. Because its density is low, it rises into the air like a gas balloon, ultimately ascending as rapidly as 300 feet per second. Approximately ten seconds after the explosion, the luminosity of the fireball has nearly died out; the pressure of the shock wave has decreased to almost harmless proportions; and the immediate effects of the bomb are over.

There are several interesting after-effects of the explosion. A violet-coloured glow is seen at some distance from the ball of fire soon after the detonation. This is observed especially at night or in dim daylight, and is believed to be the final result of a complex series of processes started by the action of gamma radiation on the nitrogen and oxygen of the air. If the air is saturated or nearly saturated with water vapour, another phenomenon occurs. The suction wave that

follows the shock wave condenses the water vapour and creates a cloud, which is dissipated when normal atmospheric pressure is restored and the water droplets vaporize. The entire effect is over in about a second.

Suppose, as do the scientists at Los Alamos, that a "nominal atomic bomb" is exploded over your city. It is two o'clock on just such an afternoon as this. In the first great flash of light—as dazzling as 100 suns—the buildings are silhouetted against a sky of fire. Then the buildings fall.

You are over half a mile from the point beneath the bomb's burst. You are exposed to a lethal dose of nuclear radiation. You will die in about two weeks.

Within a few hours, you will experience the first effect of radiation sickness—shock. In the following day or two, you will be nauseated, vomit and have diarrhœa. Fever will follow.

A few days will pass when you will be free from all symptoms. However, profound changes will be taking place in your body. Then the earlier symptoms will return and will be followed by delirium, coma and finally death. But before this stroke of good fortune, your body will become infected, you will bleed internally, your throat will swell, your hair will fall out, and your sex organs will degenerate.

During these weeks—the weeks of agony preceding your death—you will have ample time to rejoice that your family were spared by their having been annihilated totally and instantly. When the explosion occurs, they are less than half a mile from the point directly beneath the bomb's burst, and are struck almost simultaneously by three waves of force, each one strong enough to kill.

The first (flash heat, thousands of degrees hot) and the

second (invisible, penetrating nuclear radiation, deadly gamma rays and neutrons) arrive as one. A second later, the blast wave hits, crushing the city with a gigantic pressure.

In the immediate area of the explosion, nothing is left standing. There are no walls. There are no wounded. The heat and pressure of the bomb reduce buildings and human beings to smoke and dust.

Utter destruction occurs within a half-mile radius. Small buildings made of brick or stone are overwhelmed by pressure and collapse completely. Light buildings and homes are totally demolished by blast and fire. Factories are stripped of roofing and siding; only the great steel girders, twisted and wrecked, remain. Buildings lean away from the point beneath the bomb's burst as though hit by a hurricane of gargantuan proportions.

People within half a mile of the atomic explosion are either killed by blast, crushed by falling buildings, burned to death by the intense burst of heat or given a greater-than-lethal dose of nuclear radiation.

The heat wave which precedes the blast lasts for about three seconds. It sets flash fires and chars combustible substances. Serious skin burns, of those who are exposed to the heat wave, occur within two miles of the explosion.

Burns from flash heat and ordinary flame are responsible for more than half of the deaths and three-quarters of the injuries in your city. About twenty minutes after the blast, the "fire storm" begins, blowing into the inferno from all directions, at thirty to forty miles an hour at its height.

The wave of invisible energy which produces radiation sickness—striking the human cell in the bone marrow, the blood, and the living tissues—arrives with the flash wave.

People at 4,200 feet from the explosion are killed by gamma radiation, while fatalities from neutrons occur up to half a mile. At a distance of 3,000 feet, city residents, even those protected by a 12-inch wall of concrete, have stood a better than 50 per cent. chance of being destroyed by this nuclear radiation.

These will be the effects upon you and your community if an atomic bomb, like that primitive one which killed over 78,000 people at Hiroshima, is exploded over your city. The effect that the atomic bomb will have upon posterity is still a mystery. Biological factors (chromosomes and genes) which control heredity are altered by radiation. If atomic victims refrain from propagating offspring for two or three months after exposure, the hazard of passing on changes in chromosomes can be diminished. This precaution, however, probably would not reduce the risk of passing on changes in genes. Whether the children or grandchildren of atomic victims will be human monsters, no man knows at the present time.

Approximately ten square miles of Nagasaki were destroyed by one atomic bomb. This means that 1,000 bombs of this type could devastate 10,000 square miles. New York City covers a densely populated area of about 300 square miles. From this it is apparent that, if properly placed, these 1,000 bombs could destroy thirty-three cities of the size of New York. And there is no reason why, with sufficient effort, *10,000* bombs cannot be secured.

If atomic bombs are used in that next war which must never be, it seems certain that all the principal cities of the entire world will be utterly destroyed and that all of their inhabitants will be killed. A great city such as Rome, representing almost 3,000 years of human struggle and art and sacrifice, will simply vanish

in a flash of heat and light. In 1945, J. Robert Oppenheimer stated that a single raid on United States cities alone could kill 40,000,000 of the earth's inhabitants.

It should be obvious that the chances of surviving an atomic attack are negligible. Up until a few years ago, all books, such as David Bradley's *No Place to Hide* and John Hersey's *Hiroshima*, and propaganda stressed this fact. Since the explosion of the first Soviet atomic bomb, however, the information coming from our officials has reversed itself. Now we are being told that "You too can survive an atomic attack!" and that salvation lies in hiding under a table or bed. The true situation is unfortunately quite the reverse. Moreover, the chances of surviving atomic warfare at present are much smaller than in the "good old days" of 1945, when the uranium bomb was the only threat to humanity. Today, with the possibility of the hydrogen bomb, and tomorrow, with the possibility of even deadlier weapons, the chances of survival have been lessened, if not altogether abolished.

Among the weapons which may be used in future wars, radioactive substances, to contaminate persons, objects and areas, are particularly sinister. This possibility is generally referred to as radiological warfare.

From the radioactive fission products that are manufactured in a pile, the Austrian physicist Hans Thirring has suggested that a "death sand" could be prepared. This could be done by drying a water solution of salts of the fission products on sand or metal powder. Dropped upon the streets of a city, this deadly sand would be picked up and blown about by the wind. Human beings would perish by inhaling it.

If the concentration of sand on the streets amounted to a

radioactivity of 2 curies (a curie is that amount of any radioactive substance which emits the same number of alpha rays per unit of time as 1 gram of radium) for an area roughly equal to a square yard, a normal person would receive a lethal dose by taking 500 breaths. This would occupy half an hour.

Thirring calculates that a death sand containing one-half of 1 per cent. of fission products by weight would have a radioactivity of 75,000 curies per pound. A layer of this sand sufficient to produce the deadly surface concentration of 2 curies for an area somewhat larger than a square yard would be quite invisible.

As you read this, atomic power plants all over the world are producing millions upon millions of curies per month of deadly poisons. The taxpayers of both democratic and autocratic nations are supporting these plants. It would appear that we are all accomplices in a vast and terrible suicide pact.

While the atomic bombs already exploded are appalling enough, more frightful ones are now being developed. On January 31, 1950, President Truman announced that he had given orders to the Atomic Energy Commission to work on the hydrogen bomb. Since then, Stalin has announced that Russia too has been making every effort to produce bigger and better atomic weapons. And England is also in the race.

Less than one year after Mr. Truman told the Atomic Energy Commission to try to make a hydrogen bomb, on November 16, 1951, the Commission announced that "experiments contributing" to hydrogen-bomb research had been completed recently during tests on Eniwetok Atoll in the Marshall Islands. The statement that test

officials had expressed "satisfaction" over the results as a whole was made also. Speaking of the Atomic Energy Commission's announcement, the physicist Harold C. Urey said that it "sounds like official language for a successful H-bomb."

Like the old-fashioned atomic bomb, the hydrogen bomb would derive its energy from the transformation of one element into another. But the kind of reaction involved in the new bomb would be different.

The uranium-fission bomb employs as its explosive the atoms of uranium or plutonium, two of the heaviest elements known to man. When one of these heavy atoms splits, or fissures, into two lighter, simpler atoms, energy is released. The idea of the hydrogen bomb, on the other hand, is to liberate energy by fusing, or combining, one atom each of tritium and deuterium, heavy forms of hydrogen (the lightest element known) into a heavier more complex atom —namely, that of helium. This kind of reaction occurs in the sun and stars, where hydrogen is converted into helium, with the release of energy. Thus the heaviest atoms liberate energy when they are fissioned into lighter atoms; and the lightest atoms liberate energy when they are fused into heavier ones.

In a hydrogen bomb, a high temperature is required for the thermonuclear fusion reaction. The central temperature of the exploding mass of uranium or plutonium bomb has been estimated at 50,000,000° C. From this, it is apparent that a designer of a hydrogen bomb would use a uranium or plutonium bomb as a detonator. To the fission bomb, he would add a mixture of deuterium and tritium for the fusion process.

While there are inherently narrow limits to the size of a

fission bomb, there is no limit to the size of a fusion bomb, which depends solely upon the amount of the reacting elements built into it. The hydrogen bomb can be 100 or 1,000 times as deadly as the uranium bomb.

The question has been raised frequently as to whether a hydrogen bomb could start a nuclear reaction in the earth and thus convert our planet into a star. An answer has been given by Hans A. Bethe, chief of the theoretical physics division at the Los Alamos Scientific Laboratory from 1943 to 1946. Bethe points out that the radiation produced by thermonuclear reactions deep within a star has great difficulty in escaping. Since the radiation is constantly absorbed by atoms and re-emitted in new directions, it does not ascend to the surface in a straight line but by a complicated, zigzag route. This slow escape of heat maintains the high central temperature of the star, which, in turn, maintains the fusion reactions that proceed at very high temperatures. Only a star big enough to hold its radiations for a considerable length of time is able to generate significant amounts of energy. It is estimated that 10,000 years elapse before the sun's radiation, for example, escapes. Jupiter, the largest planet in the solar system, is too small to maintain nuclear reactions, from which it follows that a hydrogen bomb could not start a nuclear reaction in the earth's atmosphere, ocean or crust and transform our globe into a blazing star. A hydrogen bomb, because of its small mass, would heat only a small volume of the earth. And even if nuclear reactions were begun, the nuclear energy would be carried off by radiation much more rapidly than it was generated; the temperature would fall quickly; and the nuclear reactions would soon stop.

It is important to keep in mind, however, that this

explanation of why an atomic explosion could not start a chain reaction in the earth and blow up our planet is entirely theoretical, not factual. Actual experiment, perhaps through the wartime use of atomic energy, may prove—too late—that it is possible to reduce the earth to a new swarm of asteroids.

The effects of a hydrogen bomb would be far more devastating than those of a uranium bomb. If an H-bomb liberating 1,000 times as much energy as the Hiroshima bomb were built, it would produce almost complete destruction of buildings in a twenty-mile-wide circle (at Hiroshima, the blast caused severe destruction in a two-mile-wide circle). The area of total destruction of such a bomb would be about 314 square miles, so that the larger cities of the world, such as Paris (30 square miles), Moscow (110 square miles) or even Greater New York (320 square miles), could be obliterated by the blast effect alone of a single atomic bomb.

The population of Paris is 2,691,473, that of Moscow 4,500,000 and that of Greater New York 7,841,000. If one well-placed hydrogen bomb could annihilate most of the population of any of the great cities of the world, what notion of the threat of this atomic weapon to humanity must man form?

The heat effects of the hydrogen bomb must also be considered. Fatal burns from the Hiroshima bomb were frequent in a radius of nearly one mile. But the hydrogen bomb would burn people to death in a circle having a diameter of forty miles or more, so that the area of heat radiation would be 1,256 square miles. Greater London, with its area of 693 square miles and population of 8,346,137, would be wiped out in a single flash.

In addition to the blast and heat radiation, there would be nuclear radiation. However, it is likely that most of the people who would receive a deadly dose of radiation from the fusion bomb would be killed in any event by the blast or flash waves or by their effects.

Persistent radioactivity would also occur. The bomb case would be made in such a way that it would become highly radioactive when pulverized by the explosion. The wind would then transport these radioactive atoms over a large part of the bombed area. Moreover, radioactive atoms would be formed on the ground by the neutrons emitted from the bomb, and the centre of the bombed country would be contaminated for some time.

In a letter (to the author) of February 29, 1952, Albert Einstein wrote: "To me it is enough to know that the continuation of the existence of human beings is in serious doubt if no supra-national solution can be achieved." It is quite obvious that Einstein was talking of the hydrogen bomb at the time.

Few persons are aware of the fact that *atomic weapons might actually annihilate the human race.* It would seem that it is now within the reach of man to cause the end of the earth as an inhabited world. Leo Szilard, who worked on the atomic bomb during the war and is now a biophysicist at the University of Chicago, has suggested a means—a 500- to 10,000-ton H-bomb which would produce enough radioactive dust to poison the entire atmosphere.

According to Szilard, the necessary deuterium can be produced. To make 10,000 tons of this hydrogen, however, James R. Arnold of the University of Chicago's Institute for Nuclear Studies estimates that it would require £40,000,000,000 and a five- to ten-year all-out

effort on the part of a major industrial nation. This amount of deuterium can be exploded in one package, or in many, assuming that hydrogen bombs can be built, of course. In such an explosion, Szilard calculates that 50 tons of neutrons will be produced. These neutrons can be absorbed in an element giving rise to a dangerous radioactive substance. Zinc or cobalt, according to Arnold, are the elements which must be used, and cobalt is the poison of choice. He sees a need for a shell of 100,000 tons of cobalt around the exploding deuterium. If distributed evenly, as a dust layer over the earth's surface, the amount of radioactivity produced would emit enough rays to kill every human being.

Arnold does not believe with Szilard, however, that the radiation could be effectively distributed in this manner. He argues that dust will be removed from the air by rain and from the land by run-off to the rivers and oceans, leaving many areas relatively clean. He concludes that it is almost certainly not true that a weapon of this kind can destroy the whole human race. But he believes it is possible that the vast majority of the race can be killed by this means and that, with the advances that are to be expected, "a repetition of this discussion ten years from today may give very different results."

Thus, within a decade, man may have the opportunity to destroy every human creature on the earth, thereby precipitating the natural end by thousands of millions of years. However, there is still time for man to exert his reason, and above all his will to live, and to avert the almost inevitable catastrophe.

If civilization is to survive, the present intolerable drift towards war must be stopped quickly. (Other civilizations

have perished because they would not learn their lessons in time.) The public, which, to a large extent, has dismissed the warning of the horrible nature of atomic warfare from its consciousness, must wake up to the seriousness of the situation. It must support those of our statesmen who realize that a revolution has taken place in science and that radical measures must be used to counteract it.

The result of this first step undoubtedly will be very modest. At most, it will lead to an international control of the weapons of war. There has been some talk of disposing of *only* atomic weapons. Such a plan would not be very effective. A losing country must inevitably use the atomic bomb before being annihilated. It is inconceivable, for example, that Hitler would not have resorted to atomic warfare before blowing himself up. If a man is desperate enough to destroy himself, he is certainly going to be desperate enough to use the Bomb.

Even world control of all weapons of violence probably would not work. Just as prohibition did not stop some people from manufacturing and selling alcoholic liquors as beverages, so international control would not stop some nations from manufacturing atomic bombs and using them in war. Nevertheless, world control is a step in the right direction. Without it, there is a certainty of disaster. With it, there is only a probability.

The necessity to be prepared for the eventuality of war is implicit in the absolute authority of the national states. It would seem that the only solution to the grave problems which face us in this modern age is a supranational state, in which all of the nations would be states in one federated unit. If the nations of the earth succeed in establishing international control of the weapons of war, and if they

collaborate loyally in carrying out their obligations, a world state might ultimately be established, and a golden age would open upon the earth. This age is within the grasp of man. Actually, the problem is not in the atomic bomb. The problem is in the hearts of men.

Seven

THE FUTURE OF THE EARTH

SEVEN

THE FUTURE OF THE EARTH

THE EARTH UPON which we live is surrounded by dangers. But, according to the main conclusions of a study of the various theories of the end of the world, it would appear that there is only one danger which is close at hand.

There will be no great change in the sun's radiation for millions of years to come. The sun is getting hotter and will have become a hundred times as hot as it is today before it is about to die; but this will not occur until A.D. 10,000,000,000, while the death of the sun will not take place until millions of years later.

A second deluge, brought on by colossal tidal waves from an approaching moon, is remoter still, being predicted for A.D. 50,000,000,000+. This catastrophe may be averted entirely. If modern theories of stellar evolution are correct, the oceans will freeze first, in which case the motion of the moon towards the earth will cease.

The sun may explode, vaporizing the planets and all their inhabitants. But the chance of the sun's becoming a nova within the next few years is only one in several thousand millions. Moreover, since it is thought that each star can explode just once in its lifetime, it may be that the sun has already gone through this stage and will not explode again.

In the coming years, comets may strike the earth's surface here and there. A comet's nucleus should hit the earth, on the average, once in approximately 80,000,000 years. Thus, before the sun reaches its maximum luminosity in A.D. 10,000,000,000, more than 100 collisions should occur. When we consider that such a collision could result in local ruin only and that the chances of a comet's falling on a thickly populated area are not great, the fear of comets ending the world becomes vanishingly small.

The chance that an asteroid might encounter the earth is very much smaller than a comet-nucleus collision. The effect would be about the same.

On the other hand, if our sun were to be hit by a passing star, the results would undoubtedly be fatal to the earth. However, such collisions are rare in the cosmical order. It has been calculated that a star of the size of our sun will collide with a similar star only once in 200,000,000,000,000,000 years.

While the astronomical possibilities of the end of the world are, as determined mathematically, remote or improbable, the end by atomic war is imminent and very close to inevitable. However, there is one superb difference between the two: the astronomical methods can hardly be prevented by man, while the end by atomic power is unique in that man has it within himself to avert it. The end by atomic power is not death, but suicide.

Thus, the picture of the end of the world in the light of modern science reveals that the earth is likely to be suitable for living beings for millions of years to come, if man does not engage in foolish personal destruction. This fact helps us to realize that we must try to leave our world a better place for those who come after us.

Astronomers have known for a long time now that law and order exist everywhere in the universe. This fact is the very basis of an auspicious future of the earth. Scientists who study double stars—groupings of two stars that go round a common centre of gravity somewhere between—have found that gravity behaves in the same manner in the remotest corner of the universe, while those who study the structure of the universe have found that every galaxy has its orderly place within the limits of space.

The solar system, which consists of the sun together with the bodies that revolve about it, is one of the most remarkable examples of order in the universe. Among the many regularities of the solar system are the following: the motion of the planets in nearly circular paths, in levels not greatly inclined to one another, and all in the same direction; the rotation of the sun in the same sense, with its equator but little inclined to the planets' paths; and the satellite systems of the larger planets, which are miniature planetary sytems, with circular paths nearly in the same level of each planet's equator, and with motion in accord with the planet's rotation (a few satellites are exceptions). Such relations as these cannot be due to chance. They must have originated by some orderly process. Also, in the solar system, the bodies obey the universal laws of gravitation.

At times, nature presents the appearance of disorder to man. On these occasions, however, man fails to perceive the harmony that pervades the whole of nature's actions. Thus, the rings of Saturn seem to be the result of a chaotic event. But it has been shown that any satellite which comes too close to its primary will be broken up by the planet's attraction. Hence, instead of being contrary to Nature, the rings

are a further expression that the same laws of Nature are found everywhere in creation.

In appreciating the law and order of the universe, the story called the "World of Chance," from *Other Arabian Nights*, by Katibah, comes to mind. Hafiz, the hero of the story, is as happy a man as can be found in all the world, until his two fine sons die from eating poisonous mushrooms. In grief, he tears his hair and bewails his lot by wishing to escape from the world of unyielding laws into a world where all that happens is governed by chance—a kinder fate, he feels.

Exhausted by his wailing, Hafiz falls asleep beneath a tree in his garden. Then, in a dream, he sees a creature not altogether an animal nor fully a human being approaching him. Its head is so large that it is quite out of proportion. Its arms are absurdly long. Its eyebrows are placed beneath its eyes. The ugly creature explains that he was born that way by chance, and that everything in the World of Chance is just as strange.

Hafiz next notices the cattle. He is told that some sheep give birth to pigs and others to lambs, and that one never can foretell which it will be. While he marvels about these things, darkness falls. He asks if it is an eclipse of the sun, and his guide replies that the sun has merely set. He learns that in the World of Chance there are no fixed days or seasons and that the darkness may last a few minutes or perhaps a month. The sun rises when it chances to rise and sets when it chances to set. Hafiz then explains how the sun behaves in a predictable way in the World of Law and Order, his native land.

Then Hafiz observes rivers that change their courses in a haphazard fashion and trees that bear all kinds of fruits and

vegetables, in addition to others on their roots. When he awakes he feels deeply grateful for a well-ordered universe, regulated by the inexorable laws of Nature.

The fact that our universe is not conducted like a circus —that the sun cannot die and that a comet cannot strike the earth without cause or reason—possesses an important influence in determining an optimistic attitude toward the future of the earth. According to the astronomical theories of the end of the world, the outlook of our planet is very promising; and unless man uses atomic energy for evil purposes, our planet should go on much the same as it is today for immense lapses of time—for millennium after millennium piled upon millenniums.

If we assume that there will be satisfactory life conditions on the earth for the next 2,000,000,000 years (which is a conservative estimate according to the theories of the end of the world), and if we assume, from the oldest fossils ever found, that life originated about 1,000,000,000 years ago, then terrestrial life might be thought of as being young.

Mankind itself is younger still, though most people of all generations have thought of our race as being old. People have looked backward to such times as the Golden Age of Greece and forward to the end of the world. Similarly, a little child thinks that his parents are very old, and misty memories of the security of his childhood remain with him always.

It is believed that man first appeared upon the earth some 1,000,000 years ago. Comparing our race to a man with a life span of 100 years, and estimating our past at 1,000,000 years and our future at 2,000,000,000, it can be calculated that *that man, at present, is eighteen days old.* An

eighteen-day-old infant is not able to sit up. He is able to cry when he is hungry or in pain. His eyes are able to follow a bright light. He is able to take food. It is no wonder, then, that our race does not reason properly and is selfish. It is still in the infant stage.

According to the scale of the life span of a man being used in this analogy, fifty years for our race is little more than a minute of its life. Yet in every half-century (especially since the age of science), not only has there been progress made in learning, but there has been an acceleration in learning over the preceding fifty years. The growth of astronomy during 1900-50, for example, was extraordinary. Among the innumerable important contributions that were made, there was the confirmation of the theory of relativity, the analysis of stellar motions, the development of the carbon cycle of stellar energy, the concept of spiral galaxies, the exploration of stellar interiors, and the designing and building of great telescopes (in 1950, telescopic power was 100 times as great as fifty years before).

In the next few decades, the major contributions may be made in the fields of cosmic physics, precise stellar spectroscopy, the unravelling of the detailed structure of the Milky Way, the mapping of the neighbourhood of our galaxy and speculation about the origin of the planetary system. According to the American astronomer, Harlow Shapley, these fields, at present, appear most obvious for future development.

Not only were there great advances in astronomy in the years of 1900-50, but important contributions were made in all the sciences during this one minute in the lifetime of our infant race. In physics, the energy of the atom's nucleus was released, thus providing man with power for

good or for ill. It is a platitude that man has gained power without wisdom. If our race does not become a little wiser in the next few years, its doom is sealed. On the other hand, given a modicum of wisdom, it will have a splendid future. The hundreds of important scientific developments in the last half-century would appear to be prophetic of a world no less wonderful than that which Alice found on stepping through the looking-glass. It is also reasonable to believe that our race, like the literal infant, will grow, change and mature while it acquires its education and starts its life work.

Without going too far into the future, and basing the picture upon the peacetime application of atomic energy, we may envisage the nature of the world after the next fifty years (or sixty seconds in the lifetime of the infant race) have elapsed.

A.D. 2000!

Space ships make a 240,000-mile journey to the moon. Travelling time is a few days, while trips to Mars and Venus, the planets flanking the earth, are accomplished within a few months.

Jet-propelled planes fly nonstop round the earth's Equator in twenty-four hours. Travelling more than 1,000 miles an hour, they keep pace with the sun's progress in the sky, so that if they start at noon, the time remains noon for each instant of the flight.

Planes carrying thousands of passengers and with as much space as a luxury liner make nonstop flights from New York to all parts of the world.

Automobiles travel for a year on a pellet of atomic energy the size of a green pea.

There are no winter traffic jams because of heavy snow.

Snow and sleet are melted as fast as they fall by a network of pipes (containing atomically generated steam) buried in the concrete carpeting of city streets.

Artificial suns mounted on tall steel towers provide sunshine at any given time for parks and beaches.

Cancer, together with many other inveterate and spreading evils, is defeated by atomic research.

There is no such thing as a rare or scarce substance. For the oceans, which are great storehouses of every known chemical element, are mined with the vast amounts of cheap energy available.

The world is permanently off the gold standard. With the aid of atomic energy, the scientist is able to transform base metals—iron and lead, for example—into gold.

It is the beginning of an era of universal and perpetual peace; loyalty is being extended more and more from the national state to a supranational group of states.

"And they shall beat their swords into ploughshares and their spears into pruning-hooks; nation shall not lift up sword against nation, neither shall they learn war any more." It may be that the day envisaged by the prophet Isaiah will arrive at last in the coming era of atomic energy, an era in which man, through the power of atomic energy, will gain wisdom, health and a great abundance of all that is desirable.

An attempt has been made to present the most reasonable uses of atomic energy within the next fifty years. It should be obvious that the development of this energy is of Promethean significance—of the same order of magnitude as when man first learned the use of fire. Fire is the basis of industrial civilization today. Atomic energy will undoubtedly be the basis of the world of tomorrow. And this new world will be

as different from the present as the present is from the days before Prometheus stole fire from heaven and taught mortals the use of it.

The arrival of the era of atomic energy depends upon three things: how soon atomic energy is turned to peaceful purposes; how soon man can produce uranium 235 or plutonium (the two sources of atomic energy that are now available to mankind) at a cost that is not prohibitive in peacetime; and how soon scientists can get the energy out of the atoms of any chemical element. It should be borne in mind that years of additional theoretical research and practical experimentation will be required before this energy is ever made fully available to work for man.

But here is what atomic energy will do when this time arrives.

Smashing the atoms in 1lb. of water will produce enough energy to heat 100,000,000 tons of water from 0° to 100° C.

The air of a single act of respiration will operate a powerful aeroplane for a year continuously.

A handful of snow will heat a large apartment house for a year.

The paper pulp in a railroad ticket will run a heavy passenger train several times round the world.

Perhaps the most revolutionary effect of atomic energy on the human being will be man's new freedom to travel between the planets. The development of atomic energy has given man a fuel powerful and concentrated enough to carry him to new worlds.

By 1975, a group of terrestrial astronomers, complete with telescopes, cameras and other scientific apparatus, will have walked upon the moon's grey surface. This prediction, made by Hayden Planetarium astronomers, is

amply justified by the work of such reputable organizations as the British Interplanetary Society and is upheld by leading authorities on rockets and space travel. Dr. Wernher von Braun, one of the scientists chiefly responsible for the development of the V-2 rocket, believes that "... the time is not too far when we will get out there [to the planets] for a look-see."

Twenty thousand people have already made reservations for the first trips to the moon, Mars, Jupiter and Saturn. A Space Travel Bureau was established at the Hayden Planetarium in June, 1950, to publicize a show about an imaginary trip through the solar system. The Planetarium announced that it would keep the applications in its archives until the first interplanetary trips are scheduled, at which time they would be turned over to the proper authorities.

From the Planetarium files comes proof that people are intellectually and emotionally prepared for space travel.

In addition to the 20,000 reservations, news stories have brought over 500 letters from people of all ages, in every walk of life and from every part of the world, requesting reservations and explaining why they wish to weigh anchor and embark upon this journey through the night. Some of the letters are practical jokes, but most come from people who seem to be tired of it all and think the opportunity of escaping this sorry earth is not at all amusing.

Mirroring contemporary life, as well as the nature of human beings at all times, these letters tell an important story.

The dream of other worlds beyond our own is at least as old as Lucian, a Greek satirist who wrote about voyages to the moon almost 2,000 years ago; and it is apparent today in this letter: "Since I was a little girl I have always

dreamed of making trips to the planets, perhaps not just myself making the trips, but mankind making them."

And then there is the letter from the old man in St. Albans, West Virginia, which said: "Having been a MOON MANIAC for many years, I have decided to send my name as a possible guest on your trip to the Moon, a trip which would bring to a realization my greatest wish. . . . I would like a guarantee that we would visit both sides of the moon, and if possible, the inside; however, you can count on me with or without any guarantees. I am now growing on 85, so you would have to hurry and take me on your first trip, or I might get weak in the knees if I wait too long. Please reserve one of the front seats and I will be there, rest assured."

Judging from the letters received by the Planetarium, there exists a large group which "seriously and faithfully believes that some day it [space travel] will be as common as driving an automobile." ". . . Looking back in retrospect at the first flight of the Wright brothers," wrote one man, "I am inclined to believe that such an excursion is not only possible, but actually quite probable in some years. . . ."

Others seem not quite so sure of this, like the five seventeen-year-old schoolgirls in Stockholm, Sweden. "Perhaps we are going to book places," they wrote, "but first we want to know a little more about it. Are you quite sure that we shall get tickets back to the earth again, because we do not want to stay alone in the universal space. How shall we be safe from the cosmic rays? Have you special clothes to us for that? How long time are we going to stay on the moon? And where do we live? In the airship?"

The same caution was expressed by twenty youngsters in the fourth grade of the American Community School in

Paris. They signed up to see the moon, Mars, Jupiter and Saturn; but first, they ". . . would like to know if the rings on Saturn will cut us in half."

A question raised by many of the letters was the cost of the trip. The practical German mind manifested itself thus: "I guess that the cost of such a flight shall be very high. According to the fare of $60-70 for intercontinental flight, I estimated a fare of $45,000—for a return flight to the Moon."

However, when interplanetary travel progresses beyond the fictional stage, the cost of a trip to the moon will probably be within the reach of everyone; in fact, the Atomic Age may create ultimately a society in which every individual would have the privileges that only millionaires have today.

Many letters were accompanied by photographs of the senders. A likely explanation is contained in this letter from Berlin: "If a passport shall be necessary to a trip to the stars, which I don't believe, but one never knows, in this case you find enclosed a snapshot." The same man would ". . . like to hear what value our westmark on the several stars has."

Still another man in Berlin was concerned especially over getting his visa in time. He suggests ". . . that the Vatican is the competent office for this matter."

Children have always hated to leave their pets behind, so that this letter was no surprise to Planetarium astronomers: "I would like you to sign me up to a tour of all the four planets. And I would like to bring my pet." Another boy wondered: "If I take my dog, will you have to charge me extra fare?"

An idea common to many letters is that expressed by a married woman in Harrisburg, Pennsylvania: "I believe I

will still be available when the first flight is scheduled. However, in the event of making a solitary journey beforehand, I request permission to assign my reservation to whomever of my heirs or consigns would be interested."

The physically and mentally ill welcome the opportunity to get out of this world, as the aged do also. They offer themselves as volunteers: "For 20 years," wrote a man in Jamaica, New York, "I've thought of a trip to the moon, or elsewhere. Not as a passenger, but as a volunteer in the first experimental trip in the rocket ship . . . but, I must remind you of one thing . . . I have infantile paralysis. . . ."

Others wish to go as part of the crew. "I would like to make this trip in the capacity of Chaplain," wrote a Father at the Catholic Mission in West Pakistan. "While the travellers will keep themselves busy with their individual earthly problems, I will occupy myself with watching over their spiritual affairs. Our visitors hope to reach the moon without accident and with success. On the way toward the moon, I will hope that our final destination is not the moon. I wish that it would be much further. Much further than Saturn, further than the sun, and even further than Alpha Centauri. Our final destination is God, the Creator of all these worlds in the heaven and the infinite beauty. Note well: they say that there isn't any water on the moon. Well, I propose to carry a container of this precious liquid so that I can administer the baptism to all the new-born there. . . ."

Most of the reservations received by the Planetarium were for Mars and the moon, Mars because of the great possibility of life on that planet. Men want to go to the moon, on the other hand, ". . . because it would be the most logical destination for a trial journey as it is the closest

planetary body to the earth . . ." or ". . . because I would like to see how high I could jump." Of course, the moon and Mars have other charms. One little girl signed up to go to Mars ". . . because I like everything red."

In transitional periods like this (despite Shakespeare's warning against exchanging known for unknown ills), many feel that anything would be better than life on this troubled planet. A man in Sweden requested a space-tour reservation, saying, "I am very afraid of the atomic bomb and wish to leave the earth as soon as possible"; while a woman in Norwood, Massachusetts, wrote: "A couple of months ago I sent and received . . . space ship, time schedule reservation from you. Gosh! Now I honestly wish that I could honestly go. Isn't there any real chance at all of anyone to ever go in this lifetime, especially me, especially now, while there is still time for anyone to go anywhere? It would be heaven to get away from this lousy earth full of war, and murdering races, colours and creeds. I honestly wish God would let me get away from this whole lousy earth, and just go somewhere where it's nice, and peaceful good, safe, and secure. I never asked to be born, and I never picked this sticky old earth. But now I choose to leave it, of my own free will and desire. Because it's no good any more, any part of it. . . ."

The moon and planets may not be such safe retreats as some people imagine, however. A boy in Battle Creek, Michigan, observes ". . . there was once life on the moon and they destroyed themselves in atomic warfare, which accounts for the craters. . . ." It is probable that some men of other planets have the same frailties as earth-men.

As numerous as the letters from people wanting to get away from a crazy time in the world's political situation

were the letters from people wanting to escape life's routine. ". . . Any planet will do, as long as I get away from the steady old grind of everyday life such as it has turned out to be here on Earth," a woman in Denver, Colorado, wrote; and a man in Arecibo, Puerto Rico, said tersely: ". . . I think this life is worth nothing."

Second only to the number of people seeking adventure in space were those with professional ambitions; a multiplicity of letters was received from adults seeking business opportunities. "Please reserve a seat for the first available flight to moon. Expect to carry at least five hundred pounds of hot dogs to sell to local inhabitants," wrote one man from Mount Rainier, Washington. "It is my choice to go to Jupiter where I intend to establish real Vegetarian Towns in which all of the inhabitants are to subsist and enjoy life in conformity with the principles of Vegetarianism," stated another from Maromas, Connecticut. Still another letter from Adrian, Michigan, read: "I'm a Cracker Salesman . . . and foresee unlimited possibilities for crackers in The Land of Cheese. Please confirm my reservation for space tour to the moon."

A man from Ohio, who has his planets mixed, wants ". . . to Be the First Man to Build a Skating Rink on Venus." (Jupiter would be a happier choice, as it is locked in miles of ice, while Venus receives twice as much heat as the earth.) And from Berlin came the request to build a hotel with a special type of bed on the moon. A picture of the "Luna Hotel" was enclosed.

It would seem, according to the letters, that man is bent on establishing an earth on the moon, rather than beginning afresh in that silent land beyond our planet and attempting to rectify some of his blunders.

Will the trouble of our world spread to the moon? Or will interplanetary travel greatly raise the conditions of life for all human beings, affording to every one of them the opportunity to develop and express such capacity as he has for truly human living and truly human work in the great common enterprise of man? At this the eleventh hour we had better pause and ask ourselves these questions. If the answer to the first question is in the affirmative, if man is unable to become just a little less silly, we had better heed the advice of one correspondent who said bitterly: "You screwballs have ruined the Earth now, so why not leave the Moon alone?" But let us hope that the answer to the second question is in the affirmative and join with the wise woman of the twentieth century from Arkansas, who wrote: ". . . and if there is anything I can do to help in this great plan, whatsoever it is no matter how humble, I would do it with thanks in my heart. Thanks for the chance to help in the betterment of mankind."

When interplanetary travel is achieved, if man finds life elsewhere in the solar system, there will be two avenues open to him: he may wage *war in heaven* or he may enjoy *co-operation between the worlds*. The former course might at least unify all the nations of the earth in face of the common danger, and the War of the Worlds would result in either earth-man's defeat and ruin or in his victory and exploitation of the defeated races for his advancement. Interplanetary co-operation seems unlikely in light of man's inability to get along with his fellows on earth. If, however, man does succeed in uniting mankind, it is conceivable that some kind of mutually profitable association with inhabitants of other planets might be established.

If the planets are uninhabited, there are also two

possibilities—of either a race between the earth nations to annex those immense territories, spreading the present struggle on earth to the distant planets, or of a united mankind developing the planets for human welfare. In addition to economic opportunities, the planets could be used as possible homes for man. By increasing the atmosphere and water supply, irrigating the desert surface, producing suitable vegetation and raising the surface temperature, Mars, for example, could be transformed into a paradise for man. Man's ingenuity and atomic power should be able to make these things possible.

If the planets prove to be unadaptable to man, however, perhaps he might adapt himself to the planets by changing his form, or perhaps the two processes could be combined for the best possible use of these alien worlds. In breeding new human types of men from Mars, the work might start with experiments on some mountain varieties of our species, such as the Tibetans, who are accustomed to a cold, arid climate and a tenuous atmosphere.

Like Alice of Wonderland fame, some readers may say about space travel, "I can't believe *that*! . . . one can't believe impossible things." Let such persons heed the advice of Harvard University's Harlow Shapley, who wrote recently:

"Astronomers must keep their eyes and ears open, watching and listening to the physicists, engineers, philosophers, geologists and chemists. They must dream of the impossible, and promptly design the best way to attain it. Already we see the glimmers of a strange dawn, of an exciting era."

While our race may endure for thousands of millions of years, it is likely that civilizations, with their great cities, will rise and fall many times. The archæologist who has

wandered among the columns of dead civilizations knows well that the world is always coming to an end. Contemporary civilization itself is on the brink of disaster. If it is destroyed by atomic warfare, however, from this—the most staggering catastrophe in the history of humanity—it is possible that man will learn his lesson to do away with war for all time. War will no longer be a threat to civilizations, unless, of course, man forgets about the catastrophe as he struggles out of the wilderness once more. On the other hand, if man succeeds in permanently unifying his world society, civilizations will probably never rise and fall again. It would seem that the only possibility would be through an onslaught from Mars or another planet, which might reduce terrestrial civilization to ashes.

It is common knowledge to the geologist that huge variations are occurring in man's physical environment. Though such variations may have been more active a thousand million years ago in a more formative period of the earth, they are still occurring and will continue to do so for a long time before the earth has finally settled down. These changes will not take place in a period of a few centuries. For continents to sink below the level of seas and new territories to emerge into the sunlight, as the result of the geological changes in the level of the earth's crust, one must reckon by thousands of thousands of years.

The surface of the earth has been transformed many times, and in A.D. 60,000,000, for instance, inhabitants of the earth will find today's world as weirdly fascinating as we find that of 60,000,000 years ago. The period from 60,000,000 to 140,000,000 years ago is known as the Late Mesozoic Era. In South America, to choose an example, a sea occupied the present site of the Andes from Colombia

to the Straits of Magellan. Another invasion occurred in the region of the Amazon Valley. The most widespread floods probably took place in early Cretaceous (the third and latest of the periods comprised in the Mesozoic Era).

At the end of the Cretaceous, the present site of the Andes was uplifted in a great chain of mountains. Earlier in the Cretaceous, there were a series of mountains, mostly in Patagonia, known now as the "Patagonides." These were worn down by erosion to a region of faint relief by the end of the Mesozoic era.

The latter part of the Cretaceous may have been cool and dry in places, owing to the uplift of great areas all over the world. Before the uplifts, the climate appears to have been relatively mild and more or less uniform. This was especially true during the great flooding of the early Cretaceous. For palms, ferns and bread-fruit were then living in Svalbard, near Spitzbergen—within a few degrees of the North Pole.

Life assemblages are changing always, and in the Late Mesozoic, in the widespread seas, a group of reptiles dwelled, as huge and hideous as any imagined in fiction. There were the ichthyosaurs, which were shaped like a large fish with their limbs modified in the shape of paddles; the plesiosaurs, "reptilean rowboats" with long necks, limbs and tails; and the mosasaurs, which superficially resembled the ichthyosaurs and were as long as 35 feet.

On the land, the dinosaurs roamed incongruously among beeches, birches, maples and oaks, for our modern plants originated at this time. Among these terrible lizards there was tyrannosaurus, the largest land-living, flesh-eating animal known. Having two feet, his head stood about 20 feet above the found, and he was approximately 45 feet

long. Ornithomimus was a slender, medium-sized, ostrich-like dinosaur having a horny beak instead of teeth, while triceratops had an exceedingly large head, in large part made up of frilled bone collar.

Two kinds of birds were present; but unlike modern types, they possessed teeth. And the air was filled with flying reptiles, which had small bodies and wing-spreads of about 25 feet. They remained in the air by means of a membrane extending from the body and hind limb to an elongated finger.

This was the world of long ago. Within a period of a few million years, there will be another vast flux and reflux of life and things: the distribution of land and sea and mountains and plains will change; and there will be a new climate, new life assemblages—and a new earth.

It would appear that man himself is here to stay, however. The general cause of extinction seems to be an inability of life forms to adapt themselves to a shifting environment. But man's one great specialization—his brain—means escape from the disasters that have stalked all other forms. For man is in a position to solve environmental problems by building cities to provide shelter and protection.

However, man is rapidly coming to hold the awesome power of self-extinction. But even if he should commit suicide, it might be that he would be reincarnated in the form of similar adaptations in the same environment millions of years later. Such instances are known to exist. Thus the crocodile-like Phytosaurs of the first period of Mesozoic time became extinct yet reappeared in the same environmental zone by way of the true crocodile in the second period. In some cases, it is believed that the death

of a dominant form destroys its enemies (man himself in the possibility of the death of human beings) along with it, so that the particular corridor is left open for renewed exploitation by a later life form which starts to evolve down the same pathway.

If man should perish, there is no reason why leaps ahead in evolution should not take off from comparatively unspecialized forms of life, in which a creature even might evolve into a form as high above present man as he is above the protozoans—organisms consisting of a single cell or group of cells not separable into different tissues, which are without mouths, blind, deaf, mute and almost wholly destitute of sensation.

Such a creation might preserve man in places devoted to works of Nature, in the manner that we collect fossils of ancient worlds today—creations which cannot die again, and with which everything mortal has ceased to be associated. Time in its most hoary aspect would invest us with a hallowed and a mystic character. The green waves would wash us in their coral beds, and after ages of ablution in a tempestuous sea, the ordeal of a central fire would complete our purification. The bones and the integuments and the meanest products of our life would thus become sainted relics which the most sensitive might handle and the most delicate might prize.

In ages to come, as the waves of the sea cover the former dwelling places of man, as the earth emerges anew—fresh and regenerated—from the abysses of the ocean, as everything terrestrial changes—mountains, plains, life assemblages, civilizations, languages and customs—the constellations, which have been watched and admired by men for so long that the date of their invention is now unknown,

will be transformed innumerable times. For the stars that compose the figures of the constellations move through space with velocities greater than those of the planets. Because of the immense distances separating us from these stars, however, their high absolute speeds result in only exceedingly small angular changes of their observed positions. But photographs of the stars taken a few years apart reveal these minute changes and permit us to predict how the sky will look in thousands of years to come.

A period as short, astronomically speaking, as 100,000 years is enough to produce a vast change in the appearance of the heavens, so that in the thousands of millions of years of the earth's existence, thousands of revolutions have occurred in the sky. What strange constellations shone down upon our globe when the only life forms were marine or fresh-water types? What curious combinations of stars were visible during the age of the dinosaurs? What constellations were above his head when man first emerged naked out of the wilderness? Owing to the immense lapses of time, these mysteries are too deep to be penetrated.

In A.D. 100,000 the patterns in the sky will be quite different from those we know at present. There will be a new heaven, and our remote descendants will have to invent novel constellations to perpetuate their legends and mythologies.

It should be pointed out that even if the stars were fixed, the motion of the solar system itself would produce, in the course of so long a period as 100,000 years, a great change in the constellations, just as the elements of a landscape dissolve and recombine in fresh groupings with the traveller's progress amid them. The sun, together with its system of planets, travels through space at a speed of 12·2 miles a

second, and in A.D. 100,000 the earth will be about 38,000,000,000,000 miles from its present place. Thus, while we are able to predict the future appearances of the constellations, the inhabitants of the earth cannot hope to see them. The earth will be at another point in space.

In the year A.D. 10,000,000,000 (according to Gamow), the universe will be filled with dead or dying stars. As the light emission of the sun sinks to the zero point, the days will be turned into nights, and the moon, which shines by reflected sunlight, will disappear from sight. The stars which will have remained will have changed their places in the darkening heavens. One after another they will go out, like the lights on a fleet of fishing vessels, which, setting sail out to sea, vanish in the gloom of night.

Eight

THE FUTURE OF THE UNIVERSE

EIGHT

THE FUTURE OF THE UNIVERSE

YOU ARE ALONE IN the universe. You are, to be exact, the sole survivor in a universe populated with dead or dying stars.

You are looking out at the heavens from a mountainside on a clear night. The sky is an immense black expanse, devoid of the myriads of stars which formerly filled it. There are no bright objects to form constellations. Only a few dim stars—scattered at huge distances—are darkly visible.

If you were to look through a telescope, you would discover that the universe is empty. That is, it would appear to be empty. For every galaxy which was visible at one time has receded and has passed beyond the limit of the observable universe. Nothing that happens within these galaxies can be observed again.

The year is 12,000,000,000 after the creation of the universe, or A.D. 10,000,000,000. Soon you will vanish from the scene; and the rest of the performance of the universe will take place without anyone to watch it. But, for the present, you are the king of your planet, or rather the emperor—no! the supreme being—of the giant universe of stars. Are you enjoying your treasures? Or are you slowly perishing from loneliness and sadness?

Ultimately, all space will assume the same temperature. Then all energy changes will be impossible. There will be no heat, no light, no life. All processes of Nature will cease.

And in this unchanging condition, the condition of maximum disorganization, the universe will exist forever.

According to one school of thought, this is what it would be like to dwell in the universe in A.D. 10,000,000,000. Whether any highly developed organisms would be in existence at that time, it is impossible to say.

If you were to look out into space beyond the confines of the Milky Way today, you would observe immense numbers of bright objects—each one a great city of stars like the galaxy to which we belong. These galaxies seem to be rushing away from each other at speeds of from hundreds to many thousands of miles a second; the universe appears to be rapidly expanding. If the galaxies really are receding from one another (as most astronomers believe they are), this extraordinary phenomenon indicates that there was a time in the remote past when all the galaxies were clustered very close together. Calculations based upon the velocities of the receding galaxies show that this condition must have existed about 2,000,000,000 years ago.

A number of theories have been advanced to explain what causes the expansion of the universe. Abbé Lemaitre, a Belgian cosmologist, suggests that the universe originated from one vast primordial atom which exploded thousands of millions of years ago. This was the first atomic bomb, and the expansion of the universe is a relic of the titanic explosion.

A more recent theory was put forth in 1950 by Fred Hoyle, a young Cambridge University astronomer. According to Hoyle, the explosion idea is unsatisfactory: thus, for example, the Milky Way shows no evidence that an explosion ever occurred.

Although Hoyle believes that every galaxy we observe to

be receding from us will in A.D. 10,000,000,000 have passed beyond the limit of the observable universe, he thinks that an observer in the Milky Way at that time will still see the same number of galaxies we do now. These galaxies will have condensed out of a tenuous gas which fills the whole of space—out of the background material, as Hoyle calls it.

The English astronomer believes that the process of galaxy formation can go on indefinitely. The background material will never be exhausted, for, according to his cosmology, new material appears to make up for that which is constantly being condensed into galaxies. That is, *there is a continuous creation; a tenuous gas is being brought into existence perpetually.*

The total rate of creation for the observable universe is about 100,000,000,000,000,000,000,000,000,000,000 tons of matter per second. And it is the appearance of this matter which drives the universe: the new material produces an outward pressure that leads to the observed expansion.

The consequences of Hoyle's theory are revolutionary, in that, with continuous creation, the universe has an infinite future. Other theories, on the other hand, wail a dirge without hope, a requiem without grandeur, over the universe's future. According to them, the universe must evolve to a final state of equilibrium—the sun and stars cold, all of creation dead and unchanging. Such a view carries with it a great philosophical difficulty, which can be expressed by the question: what significance can we ascribe to a universe whose ultimate fate is merely the "heat-death," or, as it is technically called, the condition of "maximum entropy"?

There is another recent theory which presents an

optimistic view toward the future of the universe. While some stars appear to be waning, others, according to the Dust Cloud Hypothesis of Harvard's Fred L. Whipple, are being formed.

The Dust Cloud Hypothesis was published in 1948. It begins with the fact that there are vast clouds of dust and gas hanging in the abyss of interstellar space. It has been calculated that the total mass of this material is as great as that in the stars themselves. Yet the space between the stars is so immense that the dust and gas is scattered more thinly than in the best vacuum that can be achieved on the earth.

Whipple believes that the light from stars tends to force interstellar dust into larger and larger clouds. The pressure of light is demonstrated in comets' tails, which are formed by the pressure of sunlight expelling dust and gas from the head of the comet.

Finally, a cloud will reach a mass and density sufficient for gravity to become stronger than light pressure. For a dust cloud with the same mass of material as the sun, the two forces of gravity and light pressure would be equal when the diameter of the cloud was about 6,000,000,000,000 miles. Further calculations show that such a cloud might form and collapse into a star in less than 1,000,000,000 years.

Dense, dark clouds of about the same size as the hypothetical dust cloud for which gravity equals the light pressure on dust have been discovered in each region of the Milky Way. This suggests that these small dark clouds might be stars in formation.

It seems more than likely that stars are constantly being made from cosmic dust, for stars are observed which are so brilliant that they could not have been shining for

2,000,000,000 years, the estimated age of the universe. Thus it would appear that there is a building-up process in the universe.

The magnificent conception of the eternity of nature has been expressed by great men of science and philosophy throughout the ages. The spiritistic philosopher Du Prel (1882) makes the planets rush into the dead sun to revive it again. His theory reads like a beautiful poem:

"We cannot believe that the corpses of stars should, like icy spectres, float through space until reunited with the central system which would finally be reduced to immobility by the resistance of the aether. We shall rather regard the primary nebula from which the star clusters were formed as the product of the reunion of all the stars of a cluster, whose motions, converted into light and heat, produced a temperature at which the total matter was retransformed back into a nebula—a cycle which reminds us of those 'Kalpas,' by which the Buddhists designated successive periods in the existence of the Universe, counting millions of years and separated from one another by destructions."

A closer examination convinces the philosopher, however, that the entire universe cannot be at rest at the same time; the life which perishes in one spot will be blossoming out in its most beautiful shape in another. "Like Penelope, who undid at night what her busy hands had woven during the day, Nature destroys at times its works, and we have no right to ascribe to Nature the intention of completing the texture.

"After the destruction the development of every star commences afresh, and from our standpoint of terrestrial intelligence, the deep night of total oblivion will cover everything that might in a general sense be designated as

the history of the defunct stars. No different race, no creatures destined for something higher will once become the heirs of the Earth, and nothing of all that mankind has achieved will pass over into the hands of other beings.

"Thus we find in the cosmos, in proximity, all the phases of that eternal transformation in which gravitational movement is converted into heat, and heat into movement in space. Here swarms of flaming worlds radiating in their fullest splendour, there fading star clusters, in which the variable stars indicate the period of decay, and the darkened suns attempt by a last effort to guard off the icy death. Whilst in one region the first suns begin to germinate in well-defined nebulous spheres, the delicately organized solar systems are, in other spots, once more carried out into space in the shape of diffused masses of gas. And ever anew recommences the Sisyphus labour of Nature."

Under the criticism of modern science, the theory of Du Prel shrinks to nothing. It is the idea of his system which excites our admiration, however, not its physical foundation. It may be that Fred Hoyle has at last worked out the details of a universe with an infinite future.

According to the origin of the planets set forth in the New Cosmology, there are nearly 10,000,000 planetary systems in the Milky Way alone. But of these, Hoyle estimates that there are about 1,000,000 planetary systems in which life may exist. If the solar system developed by condensation of dust clouds as proposed in Whipple's hypothesis, other planetary systems are likely to be numerous too. The Dust Cloud Hypothesis thus suggests the possibility that worlds with human or intelligent life may be quite frequent throughout the universe. In fact,

it would seem that most modern theories of planetary origin point towards the presence of a multiplicity of inhabited worlds in this great universe of stars.

There is an important truth to be learned from these modern theories of cosmogony. If science is correct in imagining that there is a continuous creation or regeneration of the universe, and if the formation of planetary systems is a frequent event, then the number of worlds in the universe must always be large. More important, since the question of whether life is rare or commonplace in the universe depends essentially upon how many planetary systems are in existence, it follows that man need not be identified with one earth alone, but may rest content in the idea that *the life universal is eternal.*

Thus modern science indicates that the universe contains cradles as well as tombs, worlds to come and worlds of long ago, and that the idea of the plurality of inhabited worlds does not apply more particularly to the present epoch than to any other.

Before the existence of the earth, there were worlds with human or intelligent life as there are now. These ancient worlds must have had their Platos, their Roosevelts, their Einsteins, their Christs and their Montaignes. One cannot think without being filled with deepest wonder of the innumerable leading spirits—vast beyond all human comprehension—who have dwelt in the universe in past times. And one can hardly keep from smiling at the annals of all those who have attempted to write the history of mankind.

When the earth ceases to exist as an inhabited world, space still will be occupied with life and planets. At the present moment, the universe is filled with clouds of

primeval gas, out of which the worlds of tomorrow will be formed. Those gaseous bodies contain within them, like the unconscious chrysalis, the possibilities of the future. All life with its history, all the great land masses, the unfathomable oceans, and all the miles of atmosphere of the planets are contained within these interstellar mists. But these beings and things will not come into existence until a long incubation of millions of years. These are the teachings of modern cosmogonic theories.

It would appear, then, that the past of the universe has been as brilliant as the present, that the future will be as the past, and that the present is of no more importance than any other time. It would also appear that life is not an accidental, meaningless and extremely fleeting episode in the history of matter. On the evidence of recent theories of origin, it is possible to say that *life is the purpose of the universe.*

Until the sixteenth century, people generally believed that the earth was the centre of the universe, and they regarded man as the central fact or final aim and end of all creation. Then in 1543 Nicholas Copernicus declared the sun to be the centre of our system. The dethroning of the earth meant that its inhabitants were reduced also in position; henceforth it was impossible to make man's importance dependent upon the position of his planet.

Surveying the universe presented by modern astronomy, however, one sees that the vast majority of bodies in it appear to exist with reference to the needs of life and consciousness, and that this will be true during the infinite duration of eternity. Thus the universe seems to have as its final aim and end not terrestrial life alone, but universal and eternal life.

A curious speculation of *planetary* life was once made by

Camille Flammarion. "The earth," he writes, "gives to man his fruits, his flocks, his treasures; life circulates, and the spring-time always returns. We might almost believe that our own existence, so weak and so transient, is but a constituent part of the long existence of the planet, like the annual leaves of the perennial tree, and that, fellow-creatures with the mosses and mildew, we vegetate for an instant on the surface of this globe only to subserve the processes of an immense planetary life which we do not comprehend."

Most people say that the end of the world will be the most ultimate, irrevocable and irretrievable of natural phenomena. But if by the end of the world one means the end of the earth as an inhabited world, then it certainly is not so. For terrestrial life will have descendants and in a sense will live on. Life will be perpetuated on other worlds than ours throughout all eternity.